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**Geochemical Characterization of Slags, Other Mine Waste, and Their  
Leachate from the Elizabeth and Ely Mines (Vermont), the Ducktown  
Mining District (Tennessee), and the Clayton Smelter Site (Idaho)**

by

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## ABSTRACT

Waste-rock material produced at historic metal mines contains elevated concentrations of potentially toxic trace elements. Two types of mine waste were examined in this study: sintered waste rock and slag. The samples were collected from the Elizabeth and Ely mines in the Vermont copper belt (Besshi-type massive sulfide deposits), from the Copper Basin mining district near Ducktown, Tennessee (Besshi-type massive sulfide deposits), and from the Clayton silver mine in the Bayhorse mining district, Idaho (polymetallic vein and replacement deposits). The data in this report are presented as a compilation with minimal interpretation or discussion. A detailed discussion and interpretation of the slag data are presented in a companion paper. Data collected from sintered waste rock and slag include: (1) bulk rock chemistry, (2) mineralogy, (3) and the distribution of trace elements among phases for the slag samples. In addition, the reactivity of the waste material under surficial conditions was assessed by examining secondary minerals formed on slag and by laboratory leaching tests using deionized water and a synthetic solution approximating precipitation in the eastern United States.

## INTRODUCTION

Abandoned mines and smelter sites commonly have mine-waste material including waste rock, flotation tailings, and slag, which contain elevated concentrations of trace elements such as Cu, Zn, and Pb. These potentially toxic trace metals may be released into the environment through natural weathering processes and have adverse effects on water quality. In this study, mine-waste material including slag and sintered waste rock was characterized by determining bulk major and trace-element chemistry, and mineral chemistry. Also, the leachability of metals was examined using a modified version of the field-leach test developed by Hageman and Briggs (2000) for the characterization of mine waste.

The suite of samples studied was collected from four mine sites. The Elizabeth and Ely mines in the Vermont copper belt in Orange County, Vermont, exploited Besshi-type massive sulfide deposits. The ores consisted of pyrrhotite, chalcopyrite, and minor sphalerite and pyrite (Offield and Slack, 1993; Slack and others, 2001). The Elizabeth mine was in operation from 1809 to 1958, and the Ely mine operated from the 1850's to 1905 (Kierstead, 2001). A variety of samples of waste rock and slag were examined from these two mines. Summaries of the geology, environmental geochemistry, and mining history of the Elizabeth and Ely mines can be found in the Society of Economic Geologists Guidebook Series, volume 35 (Crowley and others, 2001; Hammarstrom and others, 2001a; Hammarstrom and others, 2001b; Hathaway and others, 2001; Kierstead, 2001; Seal and others, 2001a; Seal and others, 2001b; and Slack and others, 2001).

Like the deposits in the Vermont copper belt, the Ducktown mining district in Polk County, Tennessee, exploited Besshi-type massive sulfide deposits. The primary ore minerals were pyrrhotite, subordinate pyrite, with minor chalcopyrite, sphalerite, magnetite, and sparse galena (Magee, 1968). The Ducktown mining district operated

from 1847 to 1987. Granulated slag (quenched in water) and calcine (ore which has been crushed, concentrated, and roasted) were collected and characterized from this site.

In contrast to the Besshi-type massive sulfide deposits of Vermont and Tennessee, the deposits in the Bayhorse mining district, Idaho, include polymetallic vein and replacement deposits (Hammarstrom and others, 2002). The major sulfide minerals are galena, sphalerite, pyrite, tetrahedrite, and chalcopyrite (Ross, 1937). A sample of air-cooled slag was collected from the Clayton smelters, which operated intermittently from the 1880's to 1902, reopened in 1913, and then again in 1935. This site smelted ore from several mines within the mining districts of Greyhound Ridge, Seafoam, Germania Basin, and Bayhorse (Wells, 1983).

This report forms the detailed analytical basis for the interpretation and discussion of petrographic and geochemical data by Piatak and others (2004). Additional data and interpretations for sintered waste rock from the Elizabeth and Ely mines, calcine from Ducktown, and two pot slag samples are included in this report.

## METHODS

The bulk chemical composition of the solid samples was determined using inductively coupled plasma-atomic emission spectrometry (ICP-AES), and inductively coupled plasma-mass spectrometry (ICP-MS) following acid-digestion by a mixture of HCl-HNO<sub>3</sub>-HClO<sub>4</sub>-HF in USGS laboratories in Denver, Colorado (Crock and others, 1999). Also, major oxide content was measured using wavelength dispersive X-ray fluorescence spectroscopy (WD-XRF) following fusion in a mixture of LiBO<sub>2</sub> and LiB<sub>4</sub>O<sub>7</sub>. Interpretation in text is based on ICP-MS for minor elements and on ICP-AES for major elements, except SiO<sub>2</sub> content, for which WD-XRF results are used. Total sulfur was measured using a LECO S analyzer. WD-XRF and LECO S analyses were performed by XRAL Laboratories, Ontario, Canada.

Mineralogical identification and the distribution of trace metals within phases was determined using transmitted- and reflected-light microscopy, X-ray diffraction analysis (XRD), scanning electron microscopy (SEM), and electron-microprobe analysis (EPMA) in USGS laboratories in Reston, Virginia. XRD was performed using a Scintag X1 automated powder diffractometer equipped with a Peltier detector with CuK $\alpha$  radiation. The XRD patterns were analyzed using Material Data Inc.'s JADE software and standard reference patterns (International Centre for Diffraction Data, 1997). SEM analyses were performed with a JEOL JSM-840 SEM equipped with a backscattered electron detector, a secondary electron detector, and a PGT X-ray energy-dispersive system. Spectra were collected using an accelerating voltage of 15-20 kV, and a specimen current of 1 to 10 nA. A JEOL JXA 8900A microprobe equipped with five wavelength-dispersive spectrometers was operated at an accelerating voltage of 15-20 kV, a beam current of 20-30 nA, and a beam diameter of up to 5  $\mu$ m. The analyses were corrected for electron beam/matrix, and instrumental drift and dead time using either a ZAF or a Phi-Rho-Z-CITZAF scheme supplied with the JEOL instrument software.

A modified version of a Field-Leach Test developed by Hageman and Briggs (2000) was performed on splits of the samples in USGS laboratories in Reston, Virginia. The samples were crushed and sieved to a diameter of less than 2 mm. Each sample was

combined with either deionized water (DIW) or a solution that approximates eastern United States precipitation (ESP) at a solution to sample ratio of 20:1. A mixture of sulfuric acid and nitric acid was added to the deionized water to adjust the pH to  $4.2 \pm 0.1$ , to produce synthetic eastern precipitation solution (U.S. E.P.A., 1994). The mixtures were shaken initially for one minute and after 24 hours filtered through  $0.45 \mu\text{m}$  nitrocellulose filters. Filtered splits were analyzed for cations by ICP-MS and ICP-AES, and for anions (sulfate and chloride) by ion chromatography (IC) in USGS laboratories in Denver, Colorado, and Ocala, Florida, respectively.

### SAMPLE DESCRIPTION

Pot slag (air-cooled) and sintered waste rock were collected from the Elizabeth and Ely mines (Figure 1 and Table 1). The molten slag produced by smelting the ore was poured into pots and then dumped in waste piles. Examples of these slag-pot casts are shown in Figure 2A and B. Two of the pot slag samples from the Elizabeth mine were subdivided as rind (first few centimeters from the chilled margin) and core, and were analyzed separately. Also, texturally distinctive splits of samples 01JH27 (Elizabeth), 01JH28 (Elizabeth), and 01JH34 (Ely) were examined separately. In contrast to the pot slag samples, the sintered waste rock consists of both ore and host rock, which was broken or crushed and heated without melting (Figure 2C).

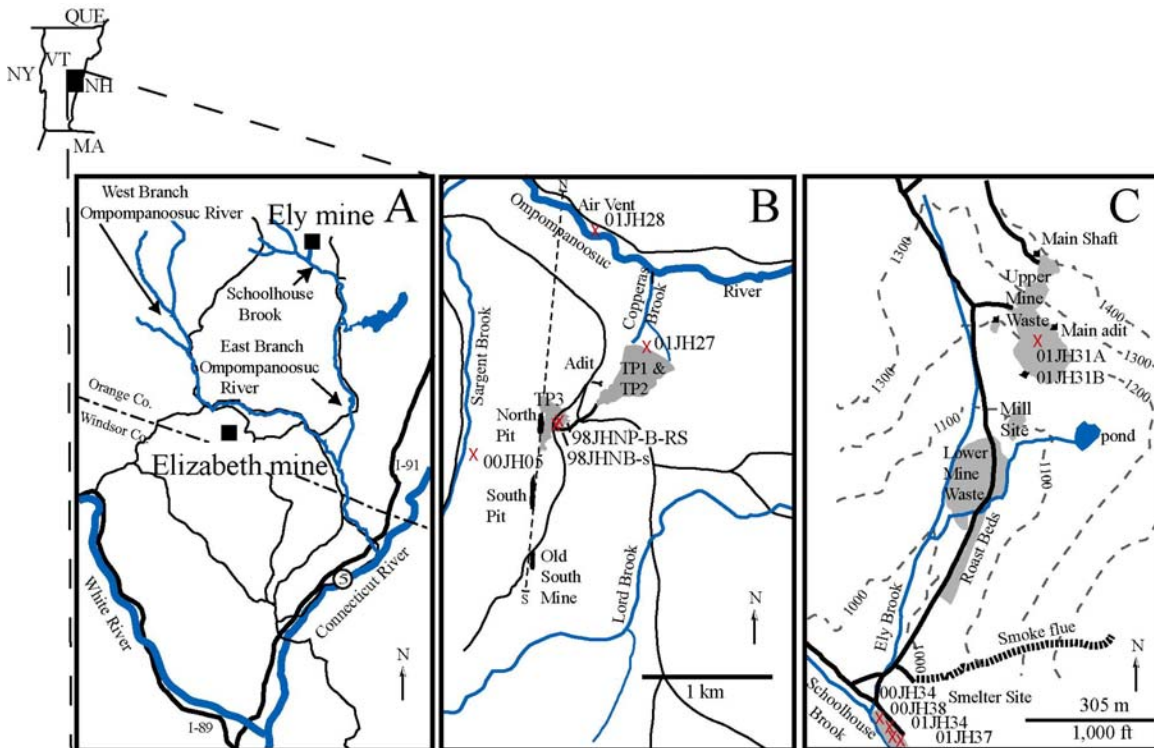


Figure 1. Locations of study areas showing sample sites in Vermont. A. Locations of Elizabeth and Ely mines. B. Sketch map of Elizabeth mine site. C. Sketch map of Ely mine site. Sample sites designated with a red "X".

Table 1. Sample descriptions.

Sample number	Mining district	Mine	Type	Sample description	Mineralogy	Comments	Location description	Smelter site	Smelting date
98JHNP-B-RS	Vermont copper belt	Elizabeth	waste rock	red; oxidized rock	quartz, feldspar, spinel, hematite, jarosite, minor mica	sintered rock	Tailings pile 3 (TP3)	n.a. <sup>a</sup>	n.a.
98JHNPB-s	Vermont copper belt	Elizabeth	waste rock	dark gray to black; coarse sand to silt-sized fragments	quartz, hematite, jarosite	sintered roasted rock	Tailings pile 3 (TP3)	n.a.	n.a.
00JH05	Vermont copper belt	Elizabeth	air-cooled slag	gray to black; flow banding with some areas botryoidal; iridescent and gray glassy surface	fayalite, spinel, sulfides	vesicular, spinifex texture	West slope of Copperas Hill	Sargent Brook	1880-1890
01JH27a	Vermont copper belt	Elizabeth	pot slag	gray to black with yellow coatings	fayalite, spinel, sulfides	vesicular, spinifex texture	Base of tailings pile (TP1)	Heckscher smelter	1905-1909
01JH27b	Vermont copper belt	Elizabeth	air-cooled slag	gray to black; flow banding and rough blocky surface; yellow coatings	fayalite, spinel, sulfides	fine-grained to glassy	Base of tailings pile (TP1)	Heckscher smelter	1905-1909
01JH28	Vermont copper belt	Elizabeth	air-cooled slag	black and dark gray layers, flow banding; brown, red, and iridescent coatings	fayalite, spinel, sulfides, quartz	vesicular, spinifex texture	North bank of the West Branch of the Ompompanoosuc River	Furnace Flat	1854-67, 1884
01JH28core	Vermont copper belt	Elizabeth	pot slag	dark gray; red coatings and glassy surfaces	fayalite, spinel, sulfides	core, spinifex and "blocky" texture	North bank of the West Branch of the Ompompanoosuc River	Furnace Flat	1854-67, 1884
01JH28rind	Vermont copper belt	Elizabeth	pot slag	dark gray; red coatings and glassy surfaces	fayalite, spinel, sulfides	rind, vesicular, spinifex texture	North bank of the West Branch of the Ompompanoosuc River	Furnace Flat	1854-67, 1884
01JH37core	Vermont copper belt	Elizabeth	pot slag	gray to black; red, brown, and iridescent coatings	fayalite, spinel, sulfides	core, spinifex texture	n.a.	n.a.	n.a.
01JH37rind	Vermont copper belt	Elizabeth	pot slag	gray to black; red, brown, and iridescent coatings	fayalite, spinel, sulfides	rind, spinifex texture	n.a.	n.a.	n.a.
00JH34	Vermont copper belt	Ely	pot slag	dark gray; red and brown coatings	fayalite, spinel, sulfides	vesicular, spinifex texture	North bank of Schoolhouse Brook	Ely	1867-1905
00JH38	Vermont copper belt	Ely	pot slag	dark gray; brown and green coatings	fayalite, spinel, sulfides	vesicular, spinifex texture	North bank of Schoolhouse Brook	Ely	1867-1905
01JH31A	Vermont copper belt	Ely	waste rock	brown, gray, red; rock fragments	quartz, feldspar, spinel, hematite, sulfide	waste rock	Upper mine waste pile	n.a.	n.a.
01JH31B	Vermont copper belt	Ely	waste rock	brown, gray, red; rock fragments	quartz, feldspar, spinel, hematite, sulfide	mine waste rock	Upper mine waste pile	n.a.	n.a.
01JH34a	Vermont copper belt	Ely	pot slag	gray; iridescent, brown, and green coatings	fayalite, spinel, sulfides	vesicular, spinifex texture	North bank of Schoolhouse Brook	Ely	1867-1905
01JH34b	Vermont copper belt	Ely	pot slag	gray to black; flow banding; iridescent, brown, and red coatings	fayalite, spinel, sulfides	vesicular, spinifex texture	North bank of Schoolhouse Brook	Ely	1867-1905
01CB23	Ducktown mining district	Ducktown	calcine	dark red; silt-sized fragments	quartz, spinel, hematite, gypsum, sulfides	sintered rock	Davis Mill Creek watershed	n.a.	n.a.
01CB25	Ducktown mining district	Ducktown	granulated slag	black; conchoidally fractured sand-sized bits	glass, hematite, sulfides	glassy	Davis Mill Creek watershed	Ducktown	1920's-1987
53JH00	Bayhorse mining district	various mines	pot slag	gray; metallic luster; iridescent, white, and green coatings	fayalite-kirschsteinite, hedenbergite, spinel, sulfide	vesicular, spinifex texture	North bank of Salmon River	Clayton smelter	1880's-1902

<sup>a</sup> not available/applicable



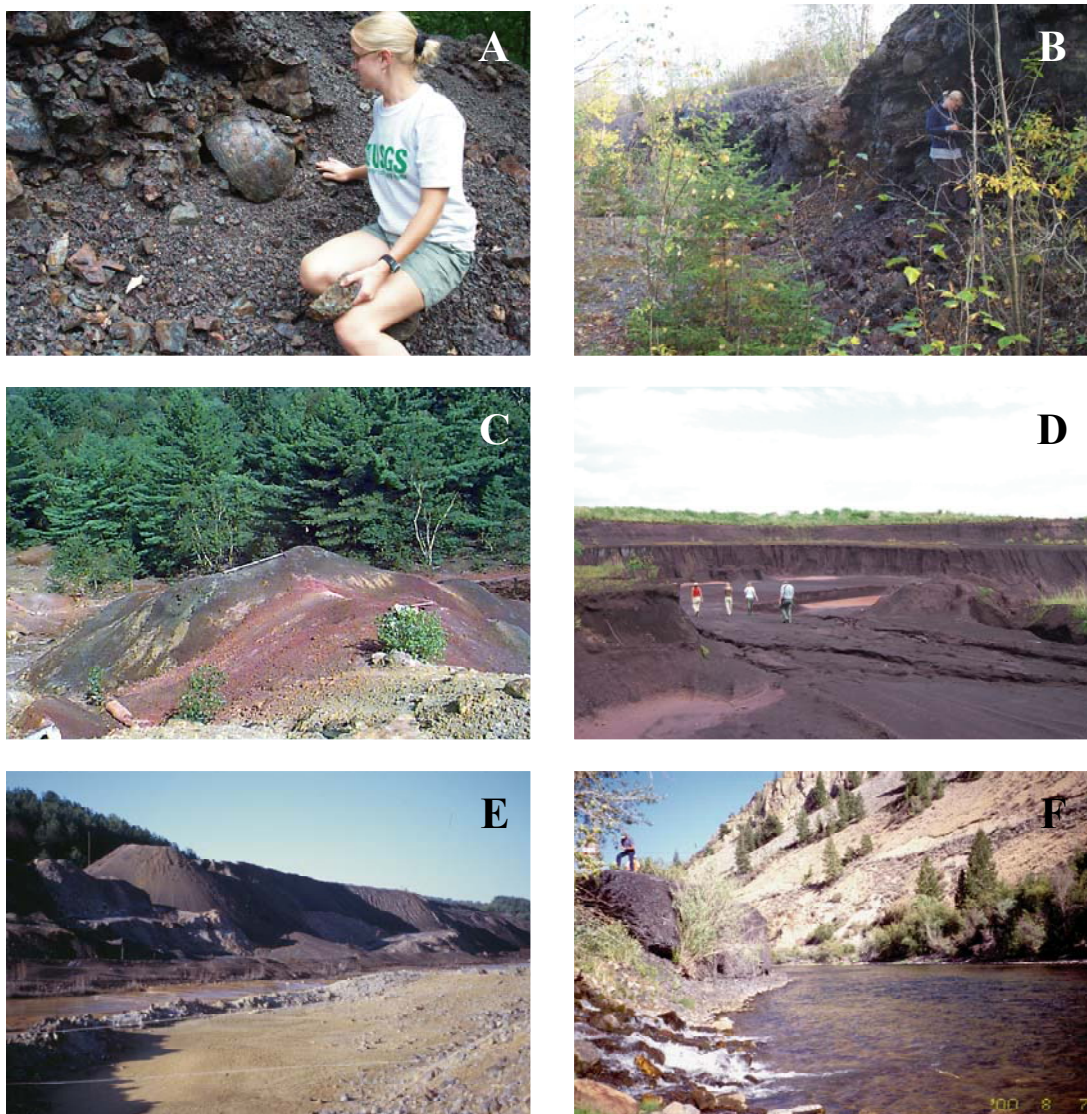


Figure 2. Representative photographs of sample sites. A. Slag pile (sample 00JH05) at the Elizabeth mine. B. Slag pile along Schoolhouse Brook at the Ely mine. C. Sintered waste rock from the Elizabeth mine, TP3 area. The black is 98JHNPB-s and the red is 98JHNP-B-RS. D. Low-sulfur calcine (sample 01CB23) at Ducktown. E. Granulated slag pile (sample 01CB25) along Davis Mill Creek at Ducktown. F. Black pile on left side of the river is air-cooled slag at the Clayton smelter site, sample 53JH00.

Low-sulfur calcine and granulated slag were collected from the Ducktown mining district (Figure 3). Mineralogical characterization and environmental impacts of waste at this site is discussed by Moyer and others (2000; 2002). The calcine is crushed, concentrated, and roasted ore (Figure 2D). In contrast, the granulated slag is the product of melting the calcine with a flux, removing the Cu matte, and cooling the waste material

in a stream of flowing water, which caused it to fracture into sand-sized particles (Anonymous-Polk County Publishers). A pile of granulated slag is located along Davis Mill Creek (Figure 2E).

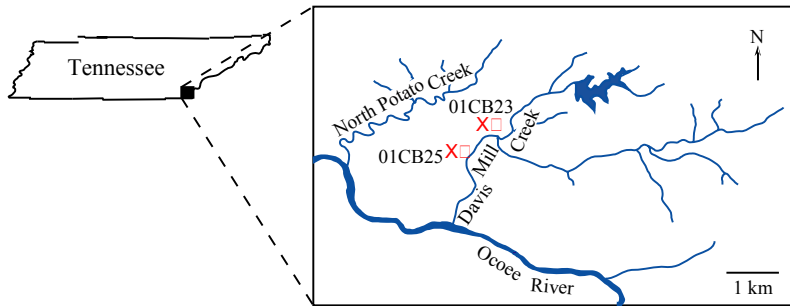


Figure 3. Location of calcine (01CB23) and granulated slag (01CB25) samples collected from the Ducktown mining district. Sample sites are designated with a red "X".

An air-cooled slag sample was collected from the Clayton smelter site (Figure 4). The slag was dumped directly on the banks of the Salmon River (Figure 2F).

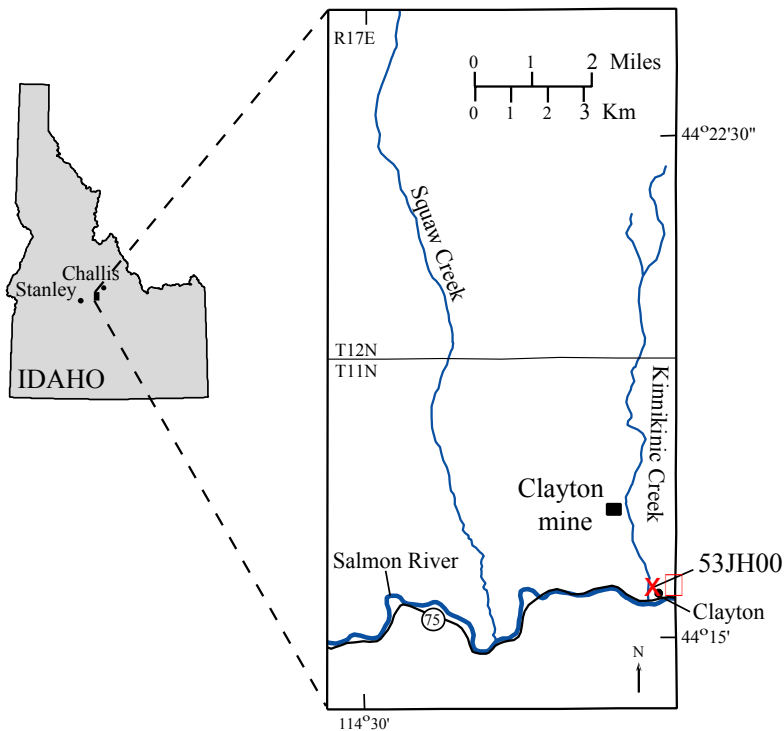


Figure 4. Location of Clayton, Idaho, smelter site and slag sample 53JH00 (designated with a red "X").

## BULK-ROCK CHEMISTRY

The bulk chemical analyses indicate that the chemical compositions of the samples are heterogeneous (Table 2). The bulk chemistry of the samples is plotted on the FeO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> and CaO-FeO-SiO<sub>2</sub> ternary diagrams in Figures 5A and B, respectively. Most samples are composed primarily of oxides of Fe and Si with varying amounts of Al and Ca. The calcine (01CB23) from Ducktown is an exception and is predominantly ferric iron oxide (Fe<sub>2</sub>O<sub>3</sub>). The waste-rock samples from the Ely mine contain higher concentrations of SiO<sub>2</sub> and lower concentrations of FeO compared to the pot slag samples. In contrast, the pot slag samples from the Elizabeth mine plot near or between the waste rock samples (Figure 5A and B). In general, the samples collected from Vermont contain higher concentrations of Al, K, and Na compared with the Ducktown and Clayton samples. Slag samples 01JH27 (Elizabeth) and 53JH00 (Clayton) contain the highest concentrations of Ca (4.1 wt. % and 3.1 wt. %, respectively), compared to all other samples (<1.9 wt. %).

The samples also display variations in trace-element concentrations (Table 2). The calcine and granulated slag from Ducktown are low in Cu (1,400 mg/kg and 2,000 mg/kg, respectively) compared to as much as 13,500 mg/kg for slag from Vermont and 7,550 mg/kg for slag from the Clayton smelter site. Several slag samples from the Vermont copper belt contain high concentrations of Co such as 00JH34 (922 mg/kg), 01JH34 (716 mg/kg), and 00JH05 (600 mg/kg). Sample 01JH27 contains the highest concentration of Cr (276 mg/kg). The Clayton smelter slag contains anomalous concentrations of several elements compared to the other samples. These elements include the following: Ag (200 mg/kg), As (555 mg/kg), Mn (22,000 mg/kg), Pb (63,000 mg/kg), Sb (1,710 mg/kg), Sn (363 mg/kg), Sr (285 mg/kg), W (175 mg/kg), and Zn (19,700 mg/kg).

## MINERALOGY

### Vermont copper belt

#### Slag

Slag samples from the Elizabeth and Ely mines are composed of olivine-group minerals, glass, spinels, sulfides, native metals, and quartz. Many of the samples display an increase in grain size from glassy rinds to megascopically crystalline interiors. For example, Figure 6A illustrates a glassy rind (top of photomicrograph) and an increase in the grain size of olivines away from this rind (bottom of photomicrograph). Flow textures are also evident in slag deposited in the molten state. The olivine-group minerals are a dominant phase in most samples and commonly display spinifex texture within a glassy or finely crystalline matrix. Radial and parallel olivine laths up to several centimeters long observed in slag samples suggest rapid cooling (Figure 6B, C, and D). Less commonly, olivine crystals in the interior of a sample are subhedral to euhedral (Figure 6E). The individual microprobe analyses and averages for olivine in each slag





Table 2. (cont.)

Element	Method	Units	Elizabeth														Ely				Ducktown				Clayton		
			98JHNP- B-RS <sup>a</sup>	98JHNP- B-RS	98JHNP- B-s <sup>a</sup>	98JHNP- B-s	00JH05 <sup>b</sup>	00JH05	01JH27	01JH27	01JH28	01JH28	01JH28	01JH28	01JH37	01JH37	00JH34 <sup>b</sup>	00JH34	00JH38 <sup>b</sup>	00JH38	01JH31A	01JH31B	01JH34	01CB23 <sup>b</sup>	01CB23	01CB25 <sup>b</sup>	01CB25
Tm	ICP-MS	mg/kg	n.a.	0.03	n.a.	0.02	n.a.	0.14	0.18	0.18	0.22	0.18	0.17	0.15	0.15	n.a.	0.18	n.a.	0.21	0.22	0.16	0.21	n.a.	0.02	n.a.	0.09	0.11
U	ICP-AES	mg/kg	n.a.	<200	n.a.	<200	<100	<200	<200	<200	<200	<200	<200	<200	<200	<100	<200	<100	<200	<200	<200	<200	<100	<200	<100	<200	<200
U	ICP-MS	mg/kg	n.a.	0.7	n.a.	0.4	n.a.	2.3	2.8	2.8	1.8	2.4	2.4	2.5	2.5	n.a.	2.8	n.a.	4.1	3.2	1.6	3.2	n.a.	0.6	n.a.	1.7	8.2
V	ICP-AES	mg/kg	n.a.	78	n.a.	42	129	93	97	94	120	120	100	98	100	192	180	196	160	120	1,300	130	22	7	55	20	50
V	ICP-MS	mg/kg	91	82	47	43	n.a.	101	112	103	128	125	104	89	94	n.a.	220	n.a.	177	116	1,430	121	n.a.	2.8	n.a.	11	46
W	ICP-MS	mg/kg	n.a.	0.7	n.a.	0.2	n.a.	1.2	1.5	1.5	2.2	2.6	2.6	1.9	2	n.a.	1.5	n.a.	1.3	0.4	0.6	1.4	n.a.	0.5	n.a.	0.4	175
Y	ICP-AES	mg/kg	<20	<4	<10	<4	10	6	10	10	10	10	10	8	8	11	9	13	10	10	10	10	<2	<4	12	5	6
Y	ICP-MS	mg/kg	n.a.	2	n.a.	1.2	n.a.	11	14	14	18	15	14	12	12	n.a.	14	n.a.	16	16	12	17	n.a.	1.6	n.a.	7.6	9.4
Yb	ICP-AES	mg/kg	n.a.	<2	n.a.	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	3	<2	2	<2	2	3	<2	3	<2	2	<2	<2
Yb	ICP-MS	mg/kg	n.a.	0.2	n.a.	0.12	n.a.	0.89	1.2	1.2	1.4	1.2	1.2	0.98	1	n.a.	1.2	n.a.	1.5	1.6	0.96	1.4	n.a.	0.1	n.a.	0.62	0.75
Zn	ICP-AES	mg/kg	n.a.	1,300	n.a.	1,000	5,740	5,400	1,800	1,800	4,500	5,700	5,700	8,100	8,200	5,560	5,500	4,670	4,600	2,200	780	4,700	1,500	1,600	13,920	7,700	16,000
Zn	ICP-MS	mg/kg	1,800	1,670	1,200	1,260	n.a.	7,650	2,310	2,350	6,160	7,640	7,390	9,870	10,200	n.a.	7,500	n.a.	6,160	2,580	744	6,070	n.a.	1,990	n.a.	9,020	19,700

<sup>a</sup> data from Hammarstrom and others (1999).

<sup>b</sup> samples were analyzed by ICP-AES in 2001 and reanalyzed by ICP-AES and ICP-MS in 2002. Discussion in text is based on 2002 analyses.

<sup>c</sup> WD-WRF results are a minimum for 53JH00 due to analytical interference caused by the high Pb and Zn concentrations.

<sup>d</sup> not analyzed or not available

<sup>e</sup> Total Fe reported as Fe<sub>2</sub>O<sub>3</sub> and was recalculated as FeO for slag samples based on mineralogical observations.

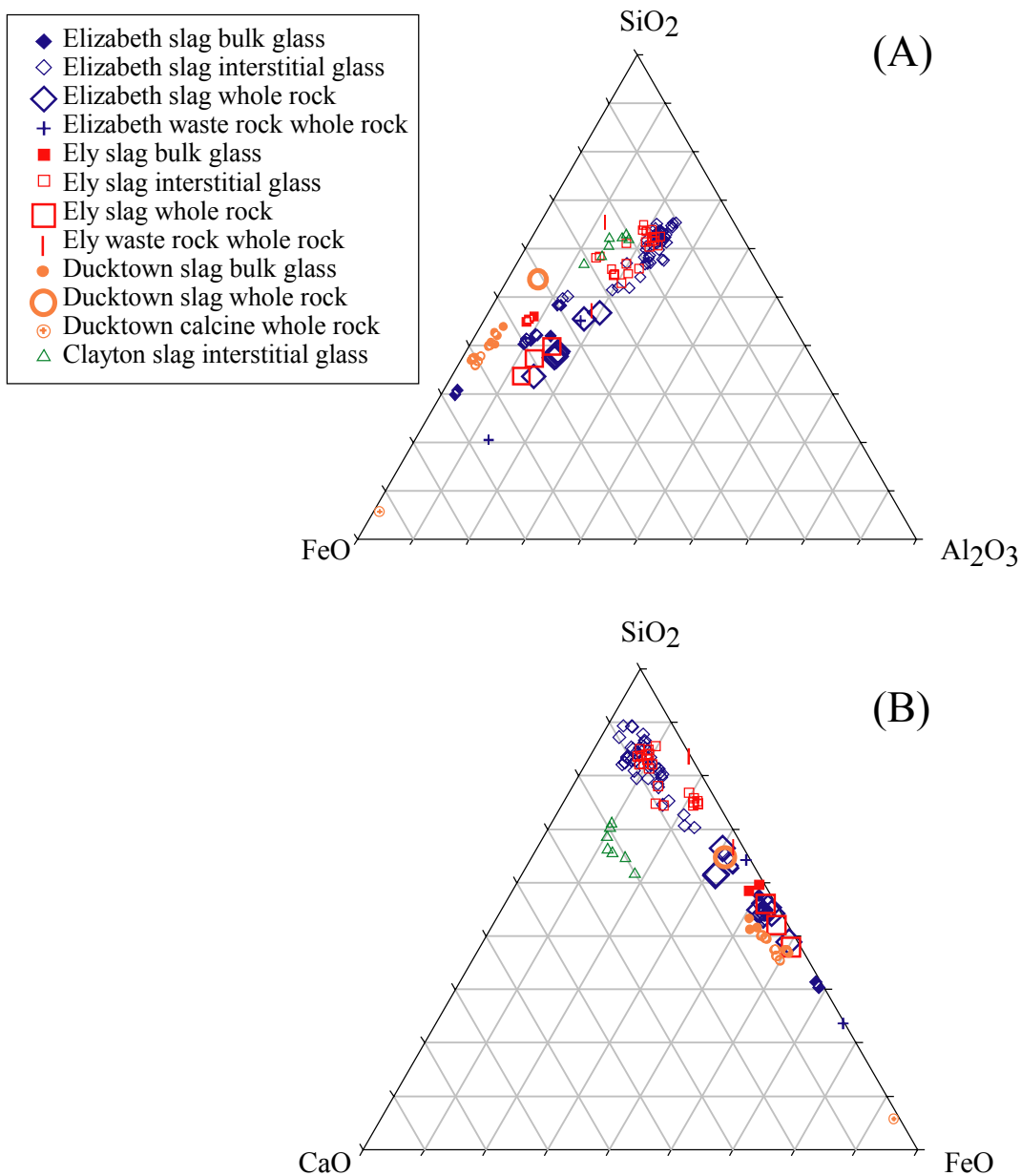


Figure 5. Glass compositions and bulk chemical compositions on A. FeO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> and B. CaO-FeO-SiO<sub>2</sub> ternary diagrams. Bulk glass analyses for slag are shown with small filled symbols, interstitial glass analyses for slag with small open symbols, whole rock analyses for slag with large open symbols and whole rock analyses for waste rock with miscellaneous symbols.

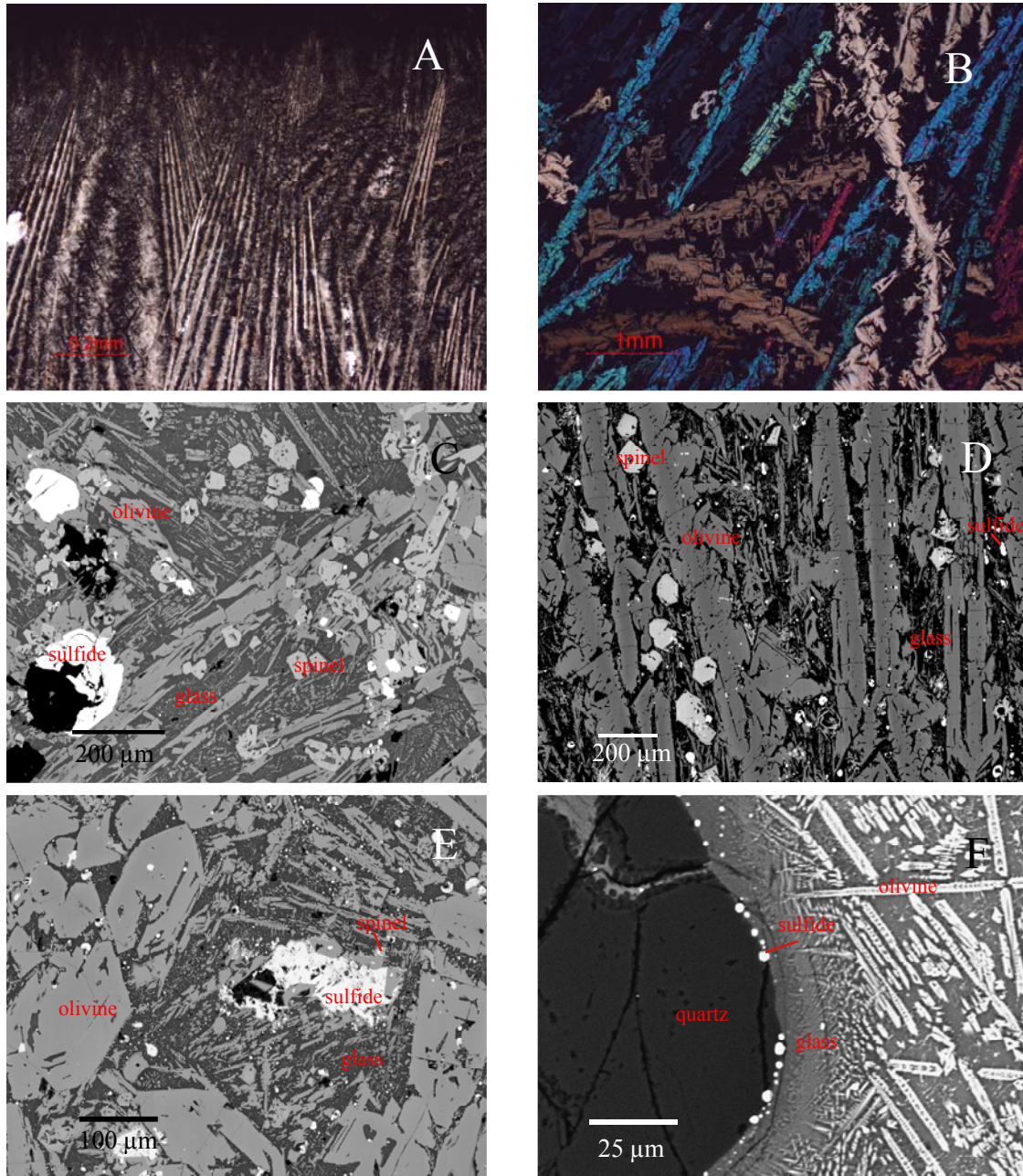


Figure 6. Photomicrographs of slag samples from the Elizabeth and Ely mines. A. Transmitted light photomicrograph of 01JH37rind showing glassy chilled margin and an increase in olivine laths away from rind. B. Transmitted light photomicrograph in crossed polars of 01JH34a illustrating high birefringence of radially-oriented skeletal olivines. C. Backscattered scanning electron (BSE) photomicrograph of 01JH28core. D. BSE photomicrograph of 01JH34a. E. BSE photomicrograph of 00JH38. F. BSE photomicrograph of 01JH28.



sample from the Elizabeth and Ely mines are given in Table 3. As shown in Figure 7, the compositions of olivine-group minerals lie along the forsterite-fayalite join. The olivine from the Elizabeth mine is more Mg-rich than that from the Ely mine. Also, the olivines from the Vermont copper belt contain up to 1.17 wt. % ZnO.

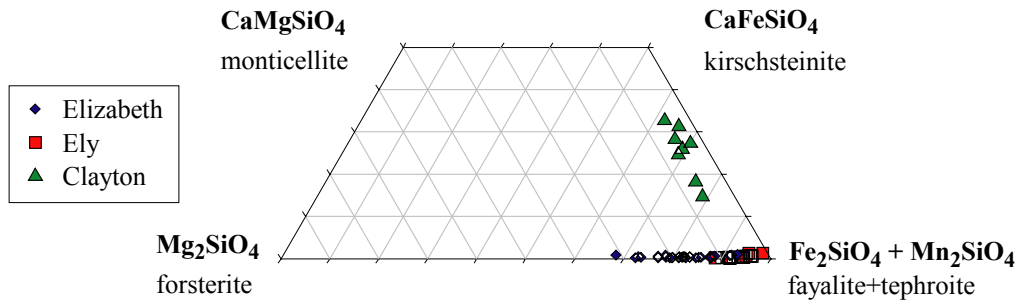


Figure 7. Olivine compositions in the forsterite-(fayalite+tephroite)-kirschsteinite-monticellite quadrilateral diagram.

The glass phase in the slag samples was categorized as either interstitial or bulk glass. The interstitial glass is the matrix material (Figure 6B-E) and the bulk glass refers to either surface glass such as the rind for a pot-slag cast (Figure 6A), chilled margins (Figure 6F), or areas that consist of only glass, such as those exhibiting flow textures, without crystalline phases. The bulk glass contains higher concentrations of Fe, and lower concentrations of Si and Al when compared to the interstitial glass (Figure 5 and Table 4). In general, bulk glass has higher concentrations of Mg, S, and Zn and lower concentrations of Na, K, and Ca relative to interstitial glass (Figure 5 and Table 4).

One slag sample from the Elizabeth mine contains quartz inclusions up to 1 mm in diameter (Figure 6F). The grain size of the olivine laths decreases towards the quartz grain. The quartz grain is thus interpreted as a small inclusion from the silica-brick used to line the smelting furnace.

Spinel in slag is euhedral to subhedral, and ranges from a micrometer to approximately a hundred micrometers in diameter (Figure 6C-E). Individual microprobe analyses and averages for spinel in each slag sample are given in Table 5. The divalent site is dominated by over 90 % ferrous iron and up to 5.3 % Zn with the rest of the site containing Mg with very minor Ca and Mn (Figure 8A). The trivalent site includes cations with a +3 valence and +4 valence, occurring in coupled substitution. This site is predominantly Fe and Al, with minor Ti, Si, and Cr (Figure 8B). The composition of the spinel in Vermont samples lies between magnetite and hercynite. In several samples, the spinels exhibit zoning. For example, the cores of a few spinel grains in sample 00JH05 contain higher concentrations of Cr than the rims, which are enriched in Al and Fe. In contrast, the core of the spinel in sample 01JH37 is enriched in Fe and Ti and depleted in Al relative to the rim.

Disseminated sulfides in slag are dominated by Fe and Cu and range from less than 1  $\mu\text{m}$  to 500  $\mu\text{m}$  in diameter (Figure 6C-F and Figure 9A). Sulfides occur as discrete grains or as admixtures of sulfides of various compositions and native metals.

Table 3. Electron-microprobe analyses of olivine and pyroxene in slag samples. Concentrations reported as weight percent.

<b>OLIVINE</b>												
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
<u>sample/analysis</u>												
00JH05												
grain 1	0.29	0.07	5.73	0.01	n.d. <sup>a</sup>	0.00	0.66	31.01	62.44	0.20	0.07	100.47
grain 2	0.13	0.08	5.98	0.00	n.d.	0.00	0.60	31.52	62.60	0.19	0.00	101.09
grain 3	0.21	0.07	9.63	0.01	n.d.	0.00	0.55	32.16	57.79	0.12	0.06	100.58
grain 4	0.19	0.08	7.16	0.00	n.d.	0.00	0.60	31.77	61.07	0.14	0.01	101.00
grain 5	0.17	0.09	3.51	0.01	n.d.	0.00	0.66	30.97	65.44	0.23	0.05	101.13
<b>average (n=5)</b>	<b>0.20</b>	<b>0.08</b>	<b>6.40</b>	<b>0.01</b>	--	<b>0.00</b>	<b>0.61</b>	<b>31.48</b>	<b>61.87</b>	<b>0.17</b>	<b>0.04</b>	<b>100.86</b>
01JH28core												
grain 1	0.14	0.18	8.21	0.00	0.03	n.d.	0.67	31.66	59.20	0.24	0.01	100.78
grain 2	0.22	0.16	8.36	0.01	0.04	n.d.	0.74	31.72	59.41	0.23	0.02	101.65
grain 3	0.08	0.18	7.75	0.00	0.02	n.d.	0.78	31.65	60.61	0.26	0.02	101.11
grain 4	0.09	0.19	8.17	0.00	0.00	n.d.	0.75	31.54	60.32	0.22	0.00	101.87
grain 5	0.17	0.22	3.26	0.00	0.04	n.d.	0.94	30.56	66.15	0.39	0.06	101.34
grain 6	0.14	0.19	2.84	0.01	0.01	n.d.	1.05	30.29	61.16	0.47	0.05	101.51
grain 7	0.12	0.20	2.33	0.00	0.00	n.d.	1.00	30.51	61.14	0.52	0.08	102.21
grain 8	0.12	0.18	8.24	0.02	n.d.	0.00	0.71	31.53	60.53	0.24	0.03	101.59
grain 9	0.12	0.21	6.81	0.03	n.d.	0.00	0.77	31.55	61.78	0.25	0.01	101.51
grain 10	0.10	0.21	6.85	0.00	n.d.	0.00	0.75	31.88	62.16	0.25	0.01	102.21
grain 11	0.09	0.21	7.44	0.01	n.d.	0.00	0.74	31.58	61.73	0.28	0.00	102.07
<b>average (n=11)</b>	<b>0.12</b>	<b>0.19</b>	<b>6.39</b>	<b>0.01</b>	<b>0.02</b>	<b>0.00</b>	<b>0.81</b>	<b>31.32</b>	<b>61.29</b>	<b>0.30</b>	<b>0.03</b>	<b>101.62</b>
01JH28rind												
grain 1	0.12	0.17	4.96	0.00	n.d.	0.00	0.84	31.23	63.94	0.35	0.05	101.65
grain 2	0.09	0.19	4.51	0.00	n.d.	0.00	0.89	31.02	64.01	0.35	0.04	101.11
grain 3	0.10	0.15	6.83	0.04	n.d.	0.00	0.85	31.46	62.16	0.24	0.03	101.87
grain 4	0.15	0.16	7.23	0.00	n.d.	0.00	0.80	31.40	61.31	0.27	0.03	101.34
<b>average (n=4)</b>	<b>0.12</b>	<b>0.17</b>	<b>5.88</b>	<b>0.01</b>	--	<b>0.00</b>	<b>0.85</b>	<b>31.28</b>	<b>62.86</b>	<b>0.30</b>	<b>0.03</b>	<b>101.49</b>
01JH28												
grain 1	2.12	0.27	12.63	0.04	n.d.	0.64	0.67	34.63	48.95	0.48	0.11	100.53
grain 2	1.94	0.29	8.88	0.05	n.d.	0.15	1.02	29.47	58.67	0.52	1.05	102.04
grain 3	0.12	0.31	9.61	0.03	n.d.	0.00	0.86	32.06	57.85	0.40	0.08	101.30
grain 4	0.34	0.28	11.42	0.00	n.d.	0.07	0.90	32.79	55.03	0.33	0.05	101.20
<b>average (n=4)</b>	<b>1.13</b>	<b>0.18</b>	<b>6.42</b>	<b>0.01</b>	--	<b>0.05</b>	<b>0.78</b>	<b>28.83</b>	<b>55.85</b>	<b>0.31</b>	<b>0.08</b>	<b>101.48</b>

Table 3. (cont.)

<b>OLIVINE</b>												
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
01JH27												
grain 1	0.05	0.08	11.51	0.01	n.d.	0.00	0.25	32.84	57.06	0.19	0.04	102.02
grain 2	0.14	0.11	8.52	0.04	n.d.	0.00	0.33	31.85	60.19	0.17	0.07	101.42
grain 3	0.10	0.08	12.12	0.03	n.d.	0.00	0.31	32.72	56.78	0.17	0.02	102.33
grain 4	0.10	0.10	9.06	0.01	n.d.	0.00	0.29	32.06	59.65	0.21	0.07	101.55
grain 5	0.21	0.09	7.57	0.04	n.d.	0.00	0.38	31.63	61.37	0.23	0.09	101.60
grain 6	0.07	0.10	8.39	0.03	n.d.	0.00	0.33	31.83	60.27	0.20	0.06	101.26
<b>average (n=6)</b>	<b>0.11</b>	<b>0.09</b>	<b>9.53</b>	<b>0.03</b>	--	<b>0.00</b>	<b>0.31</b>	<b>32.15</b>	<b>59.22</b>	<b>0.19</b>	<b>0.06</b>	<b>101.70</b>
01JH37rind												
grain 1	0.24	0.10	8.33	0.02	n.d.	0.00	0.98	31.55	59.24	0.14	0.04	100.63
grain 2	0.27	0.10	8.66	0.04	n.d.	0.00	0.97	31.51	59.73	0.14	0.08	101.50
grain 3	0.37	0.11	4.96	0.03	n.d.	0.02	1.17	31.15	63.71	0.15	0.06	101.71
grain 4	0.27	0.11	7.73	0.04	n.d.	0.00	0.92	31.30	59.68	0.14	0.07	100.24
<b>average (n=4)</b>	<b>0.29</b>	<b>0.10</b>	<b>7.42</b>	<b>0.03</b>	--	<b>0.00</b>	<b>1.01</b>	<b>31.38</b>	<b>60.59</b>	<b>0.14</b>	<b>0.06</b>	<b>101.02</b>
01JH37core												
grain 1	0.13	0.11	3.82	0.02	n.d.	0.00	1.11	30.78	65.36	0.18	0.02	101.53
grain 2	0.13	0.14	4.48	0.01	n.d.	0.00	1.10	31.16	64.17	0.16	0.05	101.38
grain 3	0.12	0.11	6.22	0.02	n.d.	0.00	1.03	31.28	61.84	0.16	0.03	100.81
grain 4	0.15	0.10	4.80	0.02	n.d.	0.00	1.01	30.83	63.23	0.19	0.07	100.40
<b>average (n=4)</b>	<b>0.13</b>	<b>0.12</b>	<b>4.83</b>	<b>0.02</b>	--	<b>0.00</b>	<b>1.06</b>	<b>31.01</b>	<b>63.65</b>	<b>0.17</b>	<b>0.04</b>	<b>101.03</b>
<b>Ely</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
00JH34												
grain 1	0.14	0.33	3.62	0.04	n.d.	0.00	0.59	30.94	64.85	0.17	0.11	100.77
grain 2	0.12	0.34	2.13	0.01	n.d.	0.00	0.64	30.79	66.15	0.18	0.05	100.42
grain 3	0.16	0.36	2.30	0.02	n.d.	0.00	0.70	30.85	65.91	0.21	0.06	100.58
grain 4	0.61	0.30	3.29	0.01	n.d.	0.08	0.61	31.92	64.27	0.23	0.06	101.37
<b>average (n=4)</b>	<b>0.26</b>	<b>0.33</b>	<b>2.84</b>	<b>0.02</b>	--	<b>0.02</b>	<b>0.63</b>	<b>31.12</b>	<b>65.30</b>	<b>0.20</b>	<b>0.07</b>	<b>100.78</b>
00JH38												
grain 1	0.17	0.23	2.59	0.03	n.d.	0.01	0.63	30.11	66.01	0.18	0.00	99.94
grain 2	1.24	0.24	0.33	0.01	n.d.	0.27	0.82	31.18	64.96	0.68	0.04	99.77
grain 3	0.18	0.24	2.16	0.03	n.d.	0.00	0.64	30.15	66.19	0.19	0.05	99.83
grain 4	0.15	0.23	3.44	0.02	n.d.	0.00	0.62	30.45	66.42	0.16	0.02	101.51
grain 5	0.10	0.21	4.57	0.02	n.d.	0.00	0.56	30.69	63.95	0.13	0.00	100.23
grain 6	0.12	0.25	3.36	0.02	n.d.	0.00	0.62	30.52	66.63	0.14	0.03	101.69
<b>average (n=6)</b>	<b>0.33</b>	<b>0.23</b>	<b>2.74</b>	<b>0.02</b>	--	<b>0.05</b>	<b>0.64</b>	<b>30.52</b>	<b>65.69</b>	<b>0.25</b>	<b>0.02</b>	<b>100.49</b>

Table 3. (cont.)

<b>OLIVINE</b>												
<b>Ely</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
01JH34a												
grain 1	0.14	0.21	3.39	0.00	n.d.	0.00	0.62	30.81	65.78	0.14	0.00	101.08
grain 2	0.14	0.23	2.10	0.00	n.d.	0.00	0.66	30.37	67.03	0.16	0.02	100.73
grain 3	0.11	0.19	3.21	0.00	n.d.	0.00	0.54	30.71	65.03	0.13	0.02	99.95
grain 4	0.11	0.24	3.31	0.01	n.d.	0.00	0.53	30.49	65.51	0.16	0.03	100.38
<b>average (n=4)</b>	<b>0.13</b>	<b>0.22</b>	<b>3.00</b>	<b>0.00</b>	--	<b>0.00</b>	<b>0.59</b>	<b>30.60</b>	<b>65.84</b>	<b>0.15</b>	<b>0.02</b>	<b>100.53</b>
01JH34b												
grain 1	0.46	0.11	1.34	0.00	n.d.	0.00	0.29	30.04	67.41	0.35	0.06	100.05
grain 2	0.36	0.12	1.49	0.00	n.d.	0.00	0.35	30.15	67.50	0.37	0.06	100.40
grain 3	3.14	0.11	1.47	0.00	n.d.	0.00	0.37	27.27	66.56	0.76	0.20	99.86
grain 4	0.09	0.27	3.98	0.02	n.d.	0.00	0.67	31.20	64.52	0.17	0.07	100.97
grain 5	0.56	0.25	1.81	0.03	n.d.	0.13	0.82	31.74	65.21	0.37	0.08	100.99
grain 6	0.03	0.27	2.52	0.00	n.d.	0.00	0.73	30.80	65.47	0.22	0.02	100.07
<b>average (n=6)</b>	<b>0.77</b>	<b>0.19</b>	<b>2.35</b>	<b>0.01</b>	--	<b>0.01</b>	<b>0.52</b>	<b>27.86</b>	<b>60.56</b>	<b>0.25</b>	<b>0.05</b>	<b>100.46</b>
<b>Clayton</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
53JH00												
grain 1 core	0.01	3.10	2.22	0.00	n.d.	0.00	1.00	31.40	45.76	16.22	0.00	99.71
grain 1 edge	0.04	3.31	2.64	0.00	n.d.	0.00	1.22	31.01	53.32	8.22	0.01	99.78
grain 2 core	0.01	2.98	2.23	0.01	n.d.	0.00	0.84	31.78	43.60	19.14	0.02	100.61
grain 2 edge	0.05	2.87	2.06	0.02	n.d.	0.00	1.03	31.61	47.66	14.85	0.03	100.17
grain 3 core	0.03	3.22	2.72	0.00	n.d.	0.00	0.91	31.38	47.86	14.25	0.00	100.37
grain 3 edge	0.03	3.14	2.52	0.02	n.d.	0.00	1.07	31.54	51.88	10.37	0.01	100.57
grain 4 core	0.03	2.68	1.25	0.01	n.d.	0.00	1.10	31.62	45.60	17.99	0.00	100.29
grain 4 edge	0.01	2.64	1.08	0.01	n.d.	0.00	1.25	31.21	47.55	15.32	0.00	99.07
<b>average (n=8)</b>	<b>0.03</b>	<b>2.99</b>	<b>2.09</b>	<b>0.01</b>	--	<b>0.00</b>	<b>1.05</b>	<b>31.45</b>	<b>47.90</b>	<b>14.54</b>	<b>0.01</b>	<b>100.07</b>
<b>PYROXENE</b>												
<b>Clayton</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	NiO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Total
sample/analysis												
53JH00												
grain 1	7.57	0.71	0.07	0.01	n.d.	0.01	0.90	41.92	26.15	21.61	0.32	99.27
grain 2	6.73	0.83	0.30	0.00	n.d.	0.00	0.73	41.51	27.31	21.68	0.25	99.33
grain 3	6.46	0.84	0.39	0.04	n.d.	0.00	0.67	41.73	27.26	21.94	0.28	99.61
grain 4	6.55	0.82	0.55	0.00	n.d.	0.00	0.60	41.28	27.44	21.67	0.27	99.18
grain 5	5.88	0.95	0.83	0.00	n.d.	0.01	0.60	42.62	26.49	22.11	0.23	99.72
<b>average (n=5)</b>	<b>6.64</b>	<b>0.83</b>	<b>0.43</b>	<b>0.01</b>	--	<b>0.00</b>	<b>0.70</b>	<b>41.81</b>	<b>26.93</b>	<b>21.80</b>	<b>0.27</b>	<b>99.42</b>

Table 4. Electron-microprobe analyses of bulk and interstitial glass in slag samples. Concentrations reported as weight percent.

<b>GLASS</b>															
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
<u>sample/analysis</u>															
00JH05															
area 1-B <sup>a</sup>	12.02	1.25	2.15	0.51	37.13	39.32	1.55	0.42	4.29	0.05	0.00	0.20	n.d. <sup>b</sup>	0.11	98.98
area 2-B	2.38	3.09	0.31	0.89	29.39	63.57	0.81	0.17	0.24	0.13	0.06	0.35	n.d.	0.19	101.60
area 3-B	2.39	3.08	0.26	0.86	28.04	63.52	0.83	0.18	0.38	0.16	0.04	1.43	n.d.	0.15	101.31
<b>average (n=3)</b>	<b>5.60</b>	<b>2.47</b>	<b>0.91</b>	<b>0.76</b>	<b>31.52</b>	<b>55.47</b>	<b>1.06</b>	<b>0.26</b>	<b>1.64</b>	<b>0.11</b>	<b>0.03</b>	<b>0.66</b>	--	<b>0.15</b>	<b>100.63</b>
area 1-I <sup>a</sup>	19.44	0.00	4.21	1.04	44.73	18.49	5.35	0.47	4.61	0.09	0.00	0.28	n.d.	0.04	98.75
area 2-I	21.08	0.00	4.68	0.56	47.53	13.69	5.13	0.29	5.53	0.07	0.00	0.21	n.d.	0.06	98.82
area 3-I	19.73	0.00	4.91	0.33	49.08	13.32	4.46	0.16	5.28	0.12	0.00	0.25	n.d.	0.00	97.65
area 4-I	19.00	0.00	4.25	0.50	46.84	16.60	5.62	0.23	4.79	0.11	0.00	0.20	n.d.	0.02	98.17
area 5-I	19.77	0.00	3.83	0.57	45.24	22.15	4.77	0.32	4.90	0.21	0.00	0.27	n.d.	0.00	102.02
area 6-I	21.22	0.00	4.79	0.90	46.92	13.34	4.80	0.33	5.00	0.09	0.00	0.32	n.d.	0.04	97.72
<b>average (n=6)</b>	<b>20.04</b>	<b>0.00</b>	<b>4.44</b>	<b>0.65</b>	<b>46.72</b>	<b>16.26</b>	<b>5.02</b>	<b>0.30</b>	<b>5.02</b>	<b>0.12</b>	<b>0.00</b>	<b>0.26</b>	--	<b>0.03</b>	<b>98.86</b>
01JH27a															
area 1-B	10.04	2.95	1.68	0.36	38.20	42.35	2.38	0.40	1.77	0.05	0.00	1.00	n.d.	0.06	101.25
area 2-B	9.65	2.60	1.73	0.44	38.22	42.40	2.34	0.43	1.74	0.13	0.07	0.89	n.d.	0.06	100.70
area 3-B	9.66	2.39	1.60	0.35	37.55	44.45	2.25	0.44	1.88	0.03	0.10	0.94	n.d.	0.07	101.71
<b>average (n=3)</b>	<b>9.78</b>	<b>2.65</b>	<b>1.67</b>	<b>0.38</b>	<b>37.99</b>	<b>43.07</b>	<b>2.32</b>	<b>0.42</b>	<b>1.80</b>	<b>0.07</b>	<b>0.06</b>	<b>0.94</b>	--	<b>0.06</b>	<b>101.22</b>
area 1-I	19.99	0.15	2.25	0.32	48.56	16.70	5.65	0.86	4.29	0.04	0.06	0.20	n.d.	0.01	99.06
area 2-I	20.35	0.14	3.96	0.39	48.59	16.21	4.32	0.72	3.41	0.12	0.00	0.19	n.d.	0.03	98.42
area 3-I	20.03	0.14	3.77	0.18	51.80	11.96	5.99	0.70	3.72	0.10	0.00	0.14	n.d.	0.02	98.54
area 4-I	19.18	0.04	3.82	0.23	53.14	11.54	6.16	0.49	3.29	0.02	0.08	0.19	n.d.	0.00	98.18
area 5-I	17.33	0.08	1.81	0.26	43.74	23.01	5.42	0.62	4.33	0.54	0.00	4.11	n.d.	0.06	101.32
<b>average (n=5)</b>	<b>19.37</b>	<b>0.11</b>	<b>3.12</b>	<b>0.27</b>	<b>49.17</b>	<b>15.88</b>	<b>5.51</b>	<b>0.68</b>	<b>3.81</b>	<b>0.16</b>	<b>0.03</b>	<b>0.97</b>	--	<b>0.02</b>	<b>99.11</b>
01JH28															
area 1-B	13.05	2.78	1.88	0.49	45.62	24.65	3.57	0.51	2.71	0.39	0.00	0.61	n.d.	0.03	96.28
area 2-B	10.64	3.81	1.38	0.78	41.92	34.22	2.77	0.51	2.14	0.26	0.00	0.51	n.d.	0.08	99.01
<b>average (n=2)</b>	<b>11.84</b>	<b>3.29</b>	<b>1.63</b>	<b>0.64</b>	<b>43.77</b>	<b>29.43</b>	<b>3.17</b>	<b>0.51</b>	<b>2.42</b>	<b>0.32</b>	<b>0.00</b>	<b>0.56</b>	--	<b>0.06</b>	<b>97.65</b>
area 1-I	10.41	4.22	1.50	0.69	43.72	33.77	2.82	0.41	1.94	0.16	0.00	0.37	n.d.	0.05	100.05
area 2-I	10.68	3.95	1.23	0.67	42.77	31.76	2.77	0.39	3.16	0.22	0.00	0.38	n.d.	0.08	98.04
area 3-I	17.16	0.31	1.71	0.89	44.50	24.80	4.48	2.88	4.73	0.00	0.02	0.13	n.d.	0.02	101.62
area 4-I	17.71	0.35	3.94	0.42	54.79	11.71	4.04	0.57	4.62	0.11	0.07	0.18	n.d.	0.00	98.50
area 5-I	20.10	0.23	3.21	0.35	54.18	8.58	5.52	0.36	5.10	0.70	0.04	1.05	n.d.	0.04	99.44
area 6-I	19.52	0.29	1.11	0.29	53.48	8.99	6.79	0.35	6.06	0.83	0.00	1.27	n.d.	0.03	99.02
area 7-I	19.97	0.18	1.86	0.46	52.78	11.15	6.18	0.76	5.03	0.22	0.00	0.25	n.d.	0.02	98.87
<b>average (n=7)</b>	<b>16.51</b>	<b>1.36</b>	<b>2.08</b>	<b>0.54</b>	<b>49.46</b>	<b>18.68</b>	<b>4.66</b>	<b>0.82</b>	<b>4.38</b>	<b>0.32</b>	<b>0.02</b>	<b>0.52</b>	--	<b>0.03</b>	<b>99.36</b>

Table 4. (cont.)

<b>GLASS</b>															
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
01JH28core															
area 1-I	17.11	0.07	2.93	0.74	50.54	14.27	7.89	0.23	3.45	0.08	0.00	0.24	n.d.	0.02	97.56
area 2-I	18.23	0.09	3.33	0.56	52.70	12.44	6.13	0.22	4.01	0.12	0.05	0.20	n.d.	0.04	98.12
area 3-I	16.52	0.13	2.82	0.79	47.94	19.61	6.74	0.38	3.41	0.11	0.00	0.16	n.d.	0.00	98.61
<b>average (n=3)</b>	<b>17.29</b>	<b>0.10</b>	<b>3.03</b>	<b>0.70</b>	<b>50.39</b>	<b>15.44</b>	<b>6.92</b>	<b>0.28</b>	<b>3.62</b>	<b>0.10</b>	<b>0.02</b>	<b>0.20</b>	--	<b>0.02</b>	<b>98.10</b>
01JH28rind															
area 1-B	8.72	2.24	1.14	0.90	36.43	45.37	2.70	0.42	1.45	0.54	0.00	0.89	n.d.	n.d.	100.80
area 2-B	8.63	2.16	1.26	0.93	37.06	44.00	2.87	0.46	1.55	0.58	0.00	1.03	n.d.	n.d.	100.52
area 3-B	8.70	2.30	1.23	1.00	36.80	44.59	2.51	0.39	1.56	0.50	0.07	0.89	n.d.	n.d.	100.53
area 4-B	8.72	2.24	1.14	0.90	36.43	45.37	2.70	0.42	1.45	0.54	0.00	0.89	0.00	n.d.	100.80
area 5-B	8.63	2.16	1.26	0.93	37.06	44.00	2.87	0.46	1.55	0.58	0.00	1.03	0.00	n.d.	100.52
<b>average (n=5)</b>	<b>8.68</b>	<b>2.22</b>	<b>1.21</b>	<b>0.93</b>	<b>36.75</b>	<b>44.67</b>	<b>2.73</b>	<b>0.43</b>	<b>1.51</b>	<b>0.55</b>	<b>0.02</b>	<b>0.94</b>	<b>0.00</b>	n.d.	<b>100.63</b>
area 1-I	18.73	0.10	2.87	0.59	53.52	11.69	7.61	0.25	3.60	0.09	0.01	0.72	n.d.	n.d.	99.78
area 2-I	18.57	0.06	2.50	0.71	53.40	11.89	8.78	0.24	3.51	0.14	0.03	0.78	n.d.	n.d.	100.62
area 3-I	19.65	0.18	2.84	0.49	52.22	12.81	6.74	0.36	4.16	0.19	0.00	0.80	n.d.	n.d.	100.44
area 4-I	20.13	0.07	2.92	0.53	52.53	11.65	7.50	0.47	4.25	0.13	0.00	0.78	n.d.	n.d.	100.95
area 5-I	18.93	0.06	2.85	0.68	52.93	11.82	8.30	0.31	3.91	0.12	0.01	0.52	n.d.	n.d.	100.43
area 6-I	20.26	0.09	2.84	0.58	52.39	12.27	7.22	0.48	4.13	0.18	0.00	0.64	n.d.	n.d.	101.08
area 7-I	19.19	0.12	2.64	0.68	51.82	13.56	7.71	0.34	3.67	0.08	0.05	0.49	0.10	n.d.	100.43
area 8-I	18.68	0.08	3.22	0.57	51.41	15.88	6.67	0.38	3.76	0.17	0.00	0.45	0.12	n.d.	101.40
area 9-I	19.65	0.18	2.84	0.49	52.22	12.81	6.74	0.36	4.16	0.19	0.00	0.80	0.00	n.d.	100.44
area 10-I	20.13	0.07	2.92	0.53	52.53	11.65	7.50	0.47	4.25	0.13	0.00	0.78	0.00	n.d.	100.95
area 11-I	18.93	0.06	2.85	0.68	52.93	11.82	8.30	0.31	3.91	0.12	0.01	0.52	0.00	n.d.	100.43
area 12-I	20.26	0.09	2.84	0.58	52.39	12.27	7.22	0.48	4.13	0.18	0.00	0.64	0.00	n.d.	101.08
<b>average (n=12)</b>	<b>19.43</b>	<b>0.10</b>	<b>2.84</b>	<b>0.59</b>	<b>52.52</b>	<b>12.51</b>	<b>7.52</b>	<b>0.37</b>	<b>3.95</b>	<b>0.14</b>	<b>0.01</b>	<b>0.66</b>	<b>0.04</b>	--	<b>100.67</b>
01JH37core															
area 1-I	18.32	0.07	3.70	0.58	51.62	15.39	4.86	0.40	4.51	0.11	0.00	0.36	n.d.	0.05	99.96
area 2-I	18.66	0.04	3.83	0.59	53.26	12.62	4.72	0.30	4.61	0.09	0.00	0.16	n.d.	0.04	98.92
area 3-I	19.27	0.04	3.85	0.57	53.32	12.94	4.76	0.32	4.73	0.06	0.00	0.10	n.d.	0.05	100.01
area 4-I	18.57	0.03	3.99	0.51	53.41	12.30	4.36	0.34	4.83	0.08	0.01	0.14	n.d.	0.00	98.57
area 5-I	19.75	0.06	4.05	0.49	53.79	9.51	4.58	0.39	5.27	0.08	0.00	0.10	n.d.	0.03	98.10
area 6-I	20.14	0.03	3.26	0.73	50.06	11.51	4.96	0.36	4.51	1.24	0.00	2.45	n.d.	0.02	99.28
<b>average (n=6)</b>	<b>19.12</b>	<b>0.05</b>	<b>3.78</b>	<b>0.58</b>	<b>52.58</b>	<b>12.38</b>	<b>4.71</b>	<b>0.35</b>	<b>4.74</b>	<b>0.28</b>	<b>0.00</b>	<b>0.55</b>	--	<b>0.03</b>	<b>99.14</b>

Table 4. (cont.)

<b>GLASS</b>															
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
<b>01JH37rind</b>															
area 1-I	18.85	0.04	3.01	1.14	49.52	16.71	4.78	0.40	3.99	0.21	0.00	0.71	n.d.	0.02	99.37
area 2-I	19.36	0.00	3.54	0.67	51.60	13.49	5.06	0.37	4.34	0.07	0.00	0.30	n.d.	0.03	98.83
area 3-I	19.61	0.03	3.28	0.85	49.41	16.05	4.66	0.61	4.26	0.25	0.04	0.24	n.d.	0.03	99.32
area 4-I	18.16	0.06	3.67	0.53	54.89	12.47	4.29	0.16	4.47	0.09	0.00	0.15	n.d.	0.03	98.97
area 5-I	20.29	0.01	3.76	0.60	54.11	9.65	4.63	0.34	4.79	0.05	0.01	0.19	n.d.	0.01	98.42
area 6-I	19.39	0.03	3.50	0.70	49.46	15.57	4.39	0.56	4.27	0.18	0.01	0.37	n.d.	0.02	98.46
<b>average (n=6)</b>	<b>19.28</b>	<b>0.03</b>	<b>3.46</b>	<b>0.75</b>	<b>51.50</b>	<b>13.99</b>	<b>4.63</b>	<b>0.41</b>	<b>4.35</b>	<b>0.14</b>	<b>0.01</b>	<b>0.33</b>	--	<b>0.02</b>	<b>98.89</b>
<b>Ely</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
<b>00JH34</b>															
area 1-I	16.43	0.13	3.18	0.56	48.33	23.88	2.45	1.12	1.95	0.25	0.02	0.57	n.d.	0.05	98.91
area 2-I	16.63	0.08	2.69	0.75	48.86	23.80	3.22	1.07	1.84	0.07	0.00	0.39	n.d.	0.04	99.44
area 3-I	15.51	0.17	2.86	0.66	49.15	23.51	2.92	0.80	1.79	0.32	0.00	0.36	n.d.	0.02	98.07
area 4-I	18.61	0.15	3.09	0.84	48.61	21.47	2.71	1.10	1.78	0.19	0.08	0.27	n.d.	0.06	98.95
area 5-I	18.47	0.09	3.09	0.75	46.94	23.34	2.38	1.61	1.82	0.16	0.00	0.33	n.d.	0.05	99.04
<b>average (n=5)</b>	<b>17.13</b>	<b>0.12</b>	<b>2.98</b>	<b>0.71</b>	<b>48.38</b>	<b>23.20</b>	<b>2.74</b>	<b>1.14</b>	<b>1.84</b>	<b>0.20</b>	<b>0.02</b>	<b>0.38</b>	--	<b>0.05</b>	<b>98.88</b>
<b>00JH38</b>															
area 1-I	16.56	0.02	3.82	0.32	47.98	19.82	6.74	0.40	2.44	0.09	0.00	0.18	n.d.	0.05	98.41
area 2-I	18.12	0.00	4.43	0.44	51.27	13.75	5.92	0.30	2.99	0.19	0.00	0.33	n.d.	0.00	97.73
area 3-I	18.56	0.02	3.70	0.47	46.27	17.97	7.19	0.57	2.69	0.13	0.00	0.18	n.d.	0.02	97.77
area 4-I	18.66	0.01	3.88	0.61	51.49	13.43	6.52	0.29	2.71	0.07	0.00	0.37	n.d.	0.02	98.05
area 5-I	18.07	0.01	4.90	0.31	52.47	13.52	5.03	0.24	3.14	0.12	0.00	0.18	n.d.	0.05	98.02
area 6-I	16.06	0.00	4.44	0.40	53.74	14.44	5.47	0.14	2.61	0.04	0.02	0.20	n.d.	0.03	97.58
area 7-I	18.42	0.00	4.54	0.45	50.43	14.69	5.62	0.27	3.00	0.17	0.00	0.19	n.d.	0.05	97.83
area 8-I	14.86	0.01	4.12	0.41	51.79	18.15	6.21	0.11	2.43	0.14	0.00	0.00	n.d.	0.04	98.27
<b>average (n=8)</b>	<b>17.41</b>	<b>0.01</b>	<b>4.23</b>	<b>0.43</b>	<b>50.68</b>	<b>15.72</b>	<b>6.09</b>	<b>0.29</b>	<b>2.75</b>	<b>0.12</b>	<b>0.00</b>	<b>0.20</b>	--	<b>0.03</b>	<b>97.96</b>
<b>01JH34a</b>															
area 1-I	18.68	0.01	4.56	0.48	52.84	13.19	5.70	0.13	3.37	0.08	0.00	0.09	n.d.	0.03	99.14
area 2-I	17.82	0.01	4.31	0.45	52.51	15.15	5.10	0.19	2.97	0.09	0.00	0.15	n.d.	0.06	98.81
area 3-I	17.47	0.00	3.88	0.48	53.89	12.99	6.39	0.14	2.51	0.18	0.00	0.29	n.d.	0.01	98.22
area 4-I	19.39	0.01	4.59	0.75	52.83	12.27	5.35	0.24	3.21	0.03	0.03	0.11	n.d.	0.01	98.82
area 5-I	20.24	0.03	5.24	0.63	52.28	13.71	3.26	0.19	3.14	0.06	0.02	0.06	n.d.	0.06	98.90
area 6-I	16.75	0.04	4.69	0.40	53.68	14.03	4.79	0.15	3.04	0.08	0.01	0.13	n.d.	0.02	97.82
<b>average (n=6)</b>	<b>18.39</b>	<b>0.02</b>	<b>4.54</b>	<b>0.53</b>	<b>53.01</b>	<b>13.55</b>	<b>5.10</b>	<b>0.17</b>	<b>3.04</b>	<b>0.09</b>	<b>0.01</b>	<b>0.14</b>	--	<b>0.03</b>	<b>98.62</b>

Table 4. (cont.)

<b>GLASS</b>															
<b>Ely</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
<b>01JH34b</b>															
area 1-B	7.29	1.56	1.18	0.52	41.95	44.29	2.01	0.39	0.86	0.12	0.01	0.70	n.d.	0.10	100.98
area 2-B	7.94	1.35	1.27	0.49	42.75	42.14	2.11	0.43	0.95	0.26	0.04	0.85	n.d.	0.13	100.70
area 3-B	7.42	1.42	1.26	0.62	42.43	43.47	1.87	0.37	0.87	0.19	0.05	0.72	n.d.	0.10	100.80
<b>average (n=3)</b>	<b>7.55</b>	<b>1.44</b>	<b>1.24</b>	<b>0.55</b>	<b>42.38</b>	<b>43.30</b>	<b>1.99</b>	<b>0.40</b>	<b>0.89</b>	<b>0.19</b>	<b>0.03</b>	<b>0.76</b>	--	<b>0.11</b>	<b>100.83</b>
area 1-I	12.87	0.41	2.46	0.41	53.27	24.99	2.77	0.47	1.76	0.08	0.06	0.16	n.d.	0.02	99.72
area 2-I	12.60	0.58	2.32	0.46	53.75	26.08	2.57	0.35	2.01	0.24	0.03	0.65	n.d.	0.06	101.70
area 3-I	16.23	0.15	2.41	0.52	56.16	14.19	4.66	0.75	1.53	0.20	0.00	0.67	n.d.	0.02	97.49
<b>average (n=3)</b>	<b>13.90</b>	<b>0.38</b>	<b>2.40</b>	<b>0.46</b>	<b>54.39</b>	<b>21.75</b>	<b>3.33</b>	<b>0.52</b>	<b>1.77</b>	<b>0.18</b>	<b>0.03</b>	<b>0.49</b>	--	<b>0.04</b>	<b>99.63</b>
<b>Ducktown</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
<b>01CB25</b>															
area 1	3.10	1.62	0.37	2.12	32.56	53.25	4.33	0.13	0.40	0.63	0.05	3.90	n.d.	n.d.	102.46
area 2	2.00	0.97	0.27	1.53	34.32	55.71	2.30	0.09	0.29	0.68	0.00	3.30	n.d.	n.d.	101.45
area 3	3.49	1.84	0.54	1.87	35.13	49.69	4.44	0.14	0.48	0.35	0.00	3.75	n.d.	n.d.	101.72
area 4	3.53	1.71	0.54	1.90	35.22	49.57	4.30	0.17	0.46	0.37	0.00	3.89	n.d.	n.d.	101.66
area 5	3.08	1.48	0.42	1.89	32.74	54.06	4.29	0.10	0.48	0.64	0.00	5.60	n.d.	n.d.	104.78
area 6	2.92	1.47	0.41	1.98	31.75	53.86	4.15	0.09	0.43	0.74	0.00	5.43	n.d.	n.d.	103.21
area 7	3.34	1.76	0.46	1.72	35.18	50.33	4.26	0.16	0.57	0.51	0.04	4.98	n.d.	n.d.	103.30
area 8	4.11	2.16	0.60	2.01	35.23	48.54	4.82	0.18	0.63	0.31	0.04	4.06	n.d.	n.d.	102.71
area 9	3.07	1.60	0.44	2.17	31.94	54.64	4.17	0.14	0.43	0.65	0.08	4.35	n.d.	n.d.	103.68
area 10	3.85	1.92	0.53	1.86	38.36	45.53	5.03	0.12	0.64	0.21	0.00	3.69	n.d.	n.d.	101.74
area 11	3.29	1.71	0.45	1.58	35.38	50.05	4.25	0.14	0.47	0.52	0.00	3.63	n.d.	n.d.	101.47
area 12	3.75	1.80	0.51	1.85	37.64	48.49	4.73	0.19	0.58	0.31	0.00	3.46	n.d.	n.d.	103.30
area 13	2.03	0.92	0.27	1.70	34.63	56.42	2.40	0.11	0.26	0.75	0.14	2.53	n.d.	n.d.	102.16
area 14	2.97	1.52	0.38	1.95	36.98	47.10	5.93	0.08	0.33	0.27	0.00	5.49	n.d.	n.d.	103.01
area 15	2.20	0.97	0.28	1.54	34.12	55.00	2.57	0.06	0.31	1.43	0.00	3.53	n.d.	n.d.	102.01
area 16	3.07	1.61	0.49	1.97	34.51	54.14	3.93	0.11	0.40	0.42	0.08	3.82	n.d.	n.d.	104.55
area 17	3.16	1.61	0.44	1.98	34.39	53.80	4.14	0.15	0.44	0.41	0.00	3.86	n.d.	n.d.	104.39
area 18	3.44	1.70	0.48	1.85	36.84	50.74	4.61	0.14	0.49	0.30	0.07	3.79	n.d.	n.d.	104.46
area 19	2.00	0.90	0.29	1.71	34.83	57.93	2.38	0.08	0.29	0.67	0.00	2.53	n.d.	n.d.	103.60
<b>average (n=19)</b>	<b>3.07</b>	<b>1.54</b>	<b>0.43</b>	<b>1.85</b>	<b>34.83</b>	<b>52.05</b>	<b>4.05</b>	<b>0.13</b>	<b>0.44</b>	<b>0.53</b>	<b>0.03</b>	<b>3.98</b>	--	--	<b>102.93</b>



Table 4. (cont.)

<b>GLASS</b>															
<b>Clayton</b>	Al <sub>2</sub> O <sub>3</sub>	MgO	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	CuO	PbO	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	CoO	Total
53JH00															
area 1-I	8.74	0.01	3.25	3.28	40.82	22.43	15.89	0.18	1.11	0.01	3.00	0.39	0.00	n.d.	99.11
area 2-I	11.18	0.01	3.43	4.09	42.85	14.90	15.51	0.36	1.30	0.02	4.46	0.66	1.37	n.d.	100.13
area 3-I	11.69	0.00	3.58	3.34	44.00	14.31	13.82	0.30	1.44	0.03	5.11	0.46	0.00	n.d.	98.08
area 4-I	12.94	0.09	3.87	2.12	45.46	15.12	15.01	0.49	1.21	0.02	3.35	0.50	0.20	n.d.	100.37
area 5-I	10.57	0.05	1.47	2.32	43.55	17.86	17.13	0.37	1.00	0.01	4.84	0.71	0.49	n.d.	100.37
area 6-I	10.51	0.03	3.54	3.00	42.26	19.60	15.63	0.30	1.41	0.02	3.20	0.49	0.48	n.d.	100.47
area 7-I	9.47	0.01	2.30	4.16	41.95	16.18	16.61	0.39	0.82	0.01	5.85	0.58	0.68	n.d.	99.01
<b>average (n=7)</b>	<b>10.73</b>	<b>0.03</b>	<b>3.06</b>	<b>3.19</b>	<b>42.99</b>	<b>17.20</b>	<b>15.66</b>	<b>0.34</b>	<b>1.18</b>	<b>0.02</b>	<b>4.26</b>	<b>0.54</b>	<b>0.46</b>	<b>--</b>	<b>99.65</b>

<sup>a</sup> B:bulk/surface, I:interstitial

<sup>b</sup> not determined

Table 5. Electron-microprobe analyses of spinel and hematite in slag samples. Concentrations reported as weight percent.

<b>SPINEL</b>															
<b>Elizabeth</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO <sup>a</sup>	Fe <sub>2</sub> O <sub>3</sub> <sup>a</sup>	CaO	TiO <sub>2</sub>	CuO	SO <sub>3</sub>	CoO	Total
<u>sample/analysis</u>															
00JH05															
grain 1	18.28	0.00	0.97	0.07	0.00	0.95	0.94	32.24	44.80	0.00	2.56	n.d. <sup>b</sup>	n.d.	n.d.	100.81
grain 2	23.67	0.03	1.06	0.06	0.00	1.12	0.58	32.92	39.74	0.04	2.04	n.d.	n.d.	n.d.	101.25
grain 3	23.89	0.01	0.50	0.05	0.00	1.31	0.67	33.61	38.58	0.00	2.31	n.d.	n.d.	n.d.	100.93
grain 4	14.09	0.02	0.54	0.05	0.00	0.98	1.25	32.21	49.53	0.02	2.34	n.d.	n.d.	n.d.	101.02
grain 5	13.88	0.01	0.82	0.36	0.00	0.78	0.91	31.51	49.54	0.03	1.97	n.d.	n.d.	n.d.	99.80
<b>average (n=5)</b>	<b>18.76</b>	<b>0.01</b>	<b>0.78</b>	<b>0.12</b>	<b>0.00</b>	<b>1.03</b>	<b>0.87</b>	<b>32.50</b>	<b>44.44</b>	<b>0.02</b>	<b>2.24</b>	--	--	--	<b>100.76</b>
01JH28core															
grain 1	10.18	0.04	0.91	1.07	0.01	0.79	0.42	31.28	54.77	0.02	2.36	n.d.	n.d.	n.d.	101.84
grain 2	10.22	0.04	0.81	0.26	0.00	0.76	0.47	30.54	53.19	0.02	2.59	n.d.	n.d.	n.d.	98.90
grain 3	9.97	0.03	0.84	0.12	0.00	0.73	0.48	30.92	54.60	0.00	2.54	n.d.	n.d.	n.d.	100.25
grain 4	9.84	0.04	0.92	0.51	0.00	0.76	0.46	31.07	55.27	0.01	2.39	n.d.	n.d.	n.d.	101.27
grain 5	9.38	0.03	0.59	0.05	0.00	0.92	0.54	31.30	55.78	0.03	2.53	n.d.	n.d.	n.d.	101.15
grain 6	9.64	0.02	0.89	0.64	0.00	0.73	0.47	31.01	55.20	0.03	2.34	n.d.	n.d.	n.d.	100.96
grain 7	8.98	0.03	0.93	1.03	0.00	0.77	0.49	30.91	55.87	0.01	2.26	n.d.	n.d.	n.d.	101.27
<b>average (n=7)</b>	<b>9.74</b>	<b>0.04</b>	<b>0.84</b>	<b>0.53</b>	<b>0.00</b>	<b>0.78</b>	<b>0.48</b>	<b>31.00</b>	<b>54.95</b>	<b>0.02</b>	<b>2.43</b>	--	--	--	<b>100.81</b>
01JH28rind															
grain 1	8.94	0.06	0.76	1.39	0.10	0.81	2.98	30.60	52.92	0.34	1.67	n.d.	n.d.	n.d.	100.57
grain 2	8.75	0.04	0.69	0.20	0.02	0.80	1.31	30.72	55.07	0.09	2.22	n.d.	n.d.	n.d.	99.90
grain 3	8.71	0.02	0.90	0.23	0.00	0.76	0.51	30.98	56.99	0.02	2.36	n.d.	n.d.	n.d.	101.47
grain 4	8.65	0.02	0.95	0.40	0.00	0.75	0.52	31.06	57.45	0.02	2.17	n.d.	n.d.	n.d.	101.99
grain 5	8.88	0.03	0.82	0.43	0.00	0.75	0.46	31.17	56.83	0.00	2.18	n.d.	n.d.	n.d.	101.54
<b>average (n=5)</b>	<b>8.78</b>	<b>0.03</b>	<b>0.82</b>	<b>0.53</b>	<b>0.02</b>	<b>0.77</b>	<b>1.16</b>	<b>30.91</b>	<b>55.85</b>	<b>0.09</b>	<b>2.12</b>	--	--	--	<b>101.09</b>
01JH37rind															
grain 1	13.57	0.05	0.47	0.24	0.01	1.45	0.73	31.84	49.19	0.00	3.88	n.d.	n.d.	n.d.	101.42
01JH37core															
grain 1	19.93	0.04	0.35	0.33	0.07	2.07	1.94	32.14	39.09	0.10	4.23	n.d.	n.d.	n.d.	100.30
grain 2	19.97	0.05	0.38	0.36	0.05	1.99	1.84	32.81	40.47	0.09	4.25	n.d.	n.d.	n.d.	102.26
grain 3	16.42	0.01	0.32	0.35	0.00	1.86	0.74	32.10	45.31	0.06	4.00	n.d.	n.d.	n.d.	101.16
<b>average (n=3)</b>	<b>18.77</b>	<b>0.04</b>	<b>0.35</b>	<b>0.35</b>	<b>0.04</b>	<b>1.97</b>	<b>1.51</b>	<b>32.35</b>	<b>41.62</b>	<b>0.08</b>	<b>4.16</b>	--	--	--	<b>101.24</b>

Table 5. (cont.).

<b>SPINEL</b>															
<b>Ely</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	Fe <sub>2</sub> O <sub>3</sub>	CaO	TiO <sub>2</sub>	CuO	SO <sub>3</sub>	CoO	Total
<b>00JH38</b>															
grain 1	18.99	0.06	0.08	0.04	0.04	1.26	1.10	33.31	41.99	0.07	4.01	n.d.	n.d.	n.d.	100.96
<b>01JH34</b>															
grain 1	9.87	0.04	0.33	0.02	0.00	0.56	0.62	31.69	54.51	0.03	2.15	n.d.	n.d.	n.d.	99.81
grain 2	9.85	0.03	0.40	0.00	0.00	0.52	0.65	31.49	54.18	0.01	2.17	n.d.	n.d.	n.d.	99.32
grain 3	9.48	0.05	0.39	1.09	0.00	0.55	0.53	31.61	54.45	0.00	1.79	n.d.	n.d.	n.d.	99.96
grain 4	9.45	0.03	0.40	0.01	0.00	0.52	0.64	31.56	54.88	0.00	2.21	n.d.	n.d.	n.d.	99.69
<b>average (n=4)</b>	<b>9.66</b>	<b>0.04</b>	<b>0.38</b>	<b>0.28</b>	<b>0.00</b>	<b>0.54</b>	<b>0.61</b>	<b>31.59</b>	<b>54.51</b>	<b>0.01</b>	<b>2.08</b>	--	--	--	<b>99.70</b>
<b>Clayton</b>															
Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	Fe <sub>2</sub> O <sub>3</sub>	CaO	TiO <sub>2</sub>	CuO	SO <sub>3</sub>	CoO	Total	
<b>53JH00</b>															
grain 1	3.03	0.64	0.12	0.06	0.00	1.41	0.99	28.60	62.23	0.39	0.92	n.d.	n.d.	n.d.	98.39
grain 2	3.27	0.60	0.18	0.05	0.00	1.21	0.98	29.50	63.33	0.35	1.13	n.d.	n.d.	n.d.	100.59
<b>average (n=2)</b>	<b>3.15</b>	<b>0.62</b>	<b>0.15</b>	<b>0.05</b>	<b>0.00</b>	<b>1.31</b>	<b>0.99</b>	<b>29.05</b>	<b>62.78</b>	<b>0.37</b>	<b>1.02</b>	--	--	--	<b>99.49</b>
<b>HEMATITE</b>															
<b>Ducktown</b>	Al <sub>2</sub> O <sub>3</sub>	MnO	MgO	Cr <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	ZnO	SiO <sub>2</sub>	FeO	Fe <sub>2</sub> O <sub>3</sub>	CaO	TiO <sub>2</sub>	CuO	SO <sub>3</sub>	CoO	Total
<b>01CB25</b>															
grain 1	n.d.	0.07	n.d.	n.d.	n.d.	0.89	0.70	n.d.	98.09	n.d.	n.d.	0.05	0.02	0.02	99.83
grain 2	n.d.	0.06	n.d.	n.d.	n.d.	0.86	0.70	n.d.	98.26	n.d.	n.d.	0.00	0.01	0.02	99.92
grain 3	n.d.	0.07	n.d.	n.d.	n.d.	0.85	0.68	n.d.	99.12	n.d.	n.d.	0.01	0.00	0.02	100.75
<b>average (n=3)</b>	--	<b>0.07</b>	--	--	--	<b>0.87</b>	<b>0.69</b>	--	<b>98.49</b>	--	--	<b>0.02</b>	<b>0.01</b>	<b>0.02</b>	<b>100.17</b>

<sup>a</sup> Fe<sup>2+</sup>/Fe<sup>3+</sup> ratio was estimated using site-occupancy constraints

<sup>b</sup> not determined

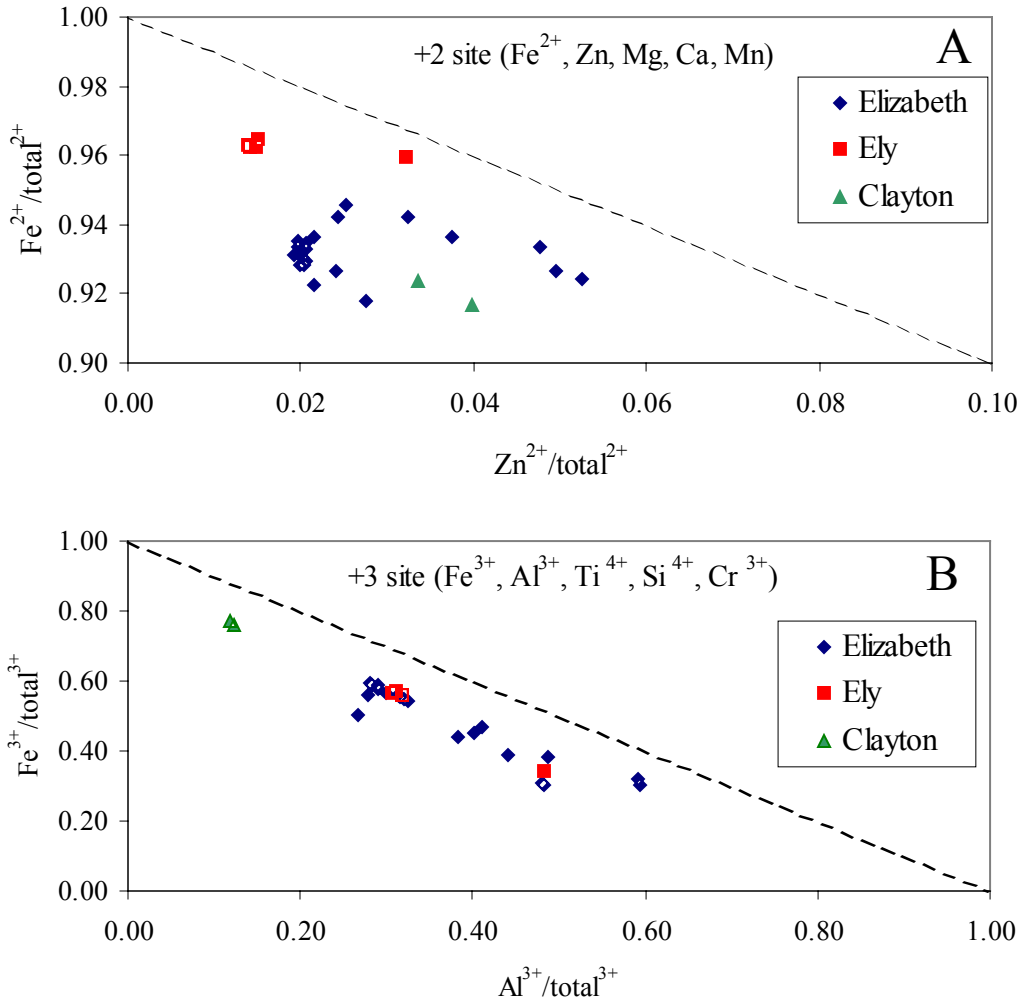


Figure 8. Composition of A. divalent and B. trivalent sites in spinel in slag samples. Appropriate valence distributions are calculated from electron-microprobe analyses assuming ideal stoichiometry. Diagonal line indicates full occupancy.

The compositions of many apparently single-phase grains (Table 6) are intermediate between discrete phases in the Cu-Fe-S system such as pyrrhotite, intermediate solid solution, and bornite-digenite, suggesting quenching at high temperatures (Cabri, 1973). Compositions tend to cluster around bornite and pyrrhotite. Many grains display small-scale exsolution as illustrated in Figure 9A and Figure 10. The concentrations of Cu, Fe, and S vary widely in a grain only 60  $\mu\text{m}$  in diameter (Figure 10).

Table 6. Electron-microprobe analyses for sulfide, metallic phases, and miscellaneous compounds in slag. Concentrations as weight percent.

<b>SULFIDES AND METALLIC PHASES</b>																	
<b>Elizabeth</b>	Fe	Mn	As	Pb	S	Cu	Co <sup>a</sup>	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
sample/phase																	
00JH05																	
Cu-Fe-S	25.12	0.00	0.02	0.00	30.84	43.75	0.03	0.01	0.02	0.00	0.18	0.00	0.00	0.00	0.00	n.d. <sup>b</sup>	100.00
Cu-Fe-S	15.09	0.01	0.00	0.00	26.42	59.06	0.02	0.01	0.03	0.00	0.06	0.00	0.00	0.00	0.00	n.d.	100.72
Cu-Fe-S	22.95	0.00	0.00	0.00	26.35	48.56	0.02	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	n.d.	97.96
Cu-Fe-S	16.80	0.00	0.00	0.00	27.24	55.34	0.01	0.01	0.05	0.00	0.08	0.00	0.00	0.00	0.00	n.d.	99.55
FeS pyrrhotite	62.87	0.00	0.00	0.00	35.23	0.69	0.12	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	n.d.	99.06
Cu-Fe-S	55.53	0.00	0.00	0.00	32.72	9.78	0.10	0.02	0.03	0.00	0.07	0.00	0.00	0.00	0.00	n.d.	98.36
FeS pyrrhotite	61.23	0.02	0.00	0.00	35.34	3.13	0.23	0.02	0.00	0.00	0.00	0.00	0.00	0.11	0.00	n.d.	100.20
FeS pyrrhotite	60.63	0.00	0.00	0.00	35.47	2.56	0.12	0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.00	n.d.	98.96
01JH27																	
Cu-Fe-S	36.00	0.00	0.01	0.00	28.07	34.18	0.03	0.04	0.01	0.00	0.10	0.00	n.d.	n.d.	n.d.	n.d.	98.51
Fe-S	73.25	0.00	0.00	0.00	24.41	0.74	1.31	0.01	0.00	0.00	0.00	0.00	n.d.	n.d.	n.d.	n.d.	99.87
FeS pyrrhotite	61.33	0.00	0.00	0.00	35.17	1.03	0.05	0.00	0.00	0.00	0.02	0.00	n.d.	n.d.	n.d.	n.d.	97.72
FeS pyrrhotite	60.95	0.00	0.00	0.00	35.89	0.79	0.13	0.00	0.00	0.00	0.02	0.00	n.d.	n.d.	n.d.	n.d.	97.88
FeS pyrrhotite	63.56	0.00	0.00	0.07	36.98	0.42	0.16	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.00	n.d.	101.35
01JH28rind																	
bornite-digenite	10.63	0.00	0.01	0.00	24.38	64.87	0.04	0.00	0.00	0.00	0.09	0.00	n.d.	n.d.	n.d.	n.d.	100.03
Cu	1.02	0.00	0.00	0.00	0.04	98.30	0.02	0.04	0.01	0.00	0.05	0.00	n.d.	n.d.	n.d.	n.d.	99.47
bornite-digenite	5.43	0.00	0.02	0.00	22.08	73.55	0.03	0.02	0.01	0.00	0.08	0.00	n.d.	n.d.	n.d.	n.d.	101.20
bornite-digenite	8.78	0.01	0.02	0.00	24.09	67.91	0.03	0.03	0.01	0.00	0.06	0.00	n.d.	n.d.	n.d.	n.d.	100.94
bornite-digenite	11.69	0.00	0.04	0.00	24.24	63.67	0.00	0.00	0.02	0.00	0.06	0.00	n.d.	n.d.	n.d.	n.d.	99.72
bornite-digenite	8.16	0.00	0.02	0.00	23.66	68.36	0.05	0.03	0.01	0.00	0.08	0.00	n.d.	n.d.	n.d.	n.d.	100.38
bornite-digenite	7.33	0.00	0.00	0.00	23.54	69.16	0.02	0.04	0.00	0.00	0.02	0.02	n.d.	n.d.	n.d.	n.d.	100.13
Cu-Fe-S	16.59	0.01	0.02	0.00	25.98	55.37	0.03	0.03	0.02	0.00	0.07	0.00	n.d.	n.d.	n.d.	n.d.	98.12
bornite-digenite	12.12	0.00	0.01	0.00	25.19	62.68	0.02	0.01	0.03	n.d.	0.07	n.d.	n.d.	0.00	n.d.	n.d.	100.14
bornite-digenite	13.64	0.00	0.00	0.00	25.38	60.24	0.01	0.02	0.01	n.d.	0.11	n.d.	n.d.	0.02	n.d.	n.d.	99.44
Cu-Fe-S	17.62	0.00	0.00	0.00	27.41	54.64	0.00	0.02	0.00	n.d.	0.06	n.d.	n.d.	0.00	n.d.	n.d.	99.78
Cu-Fe-S	29.61	0.02	0.00	0.00	32.09	35.39	0.17	0.00	0.00	n.d.	2.07	n.d.	n.d.	0.00	n.d.	n.d.	99.40
bornite-digenite	12.24	0.00	0.00	0.00	24.59	63.81	0.01	0.03	0.02	n.d.	0.06	n.d.	n.d.	0.00	n.d.	n.d.	100.78
bornite-digenite	9.67	0.00	0.00	0.00	24.18	66.42	0.03	0.03	0.05	n.d.	0.06	n.d.	n.d.	0.00	n.d.	n.d.	100.45
bornite-digenite	9.31	0.00	0.00	0.00	23.23	68.88	0.02	0.04	0.00	n.d.	0.08	n.d.	n.d.	0.00	n.d.	n.d.	101.56
Cu-Fe-S	20.95	0.00	0.02	0.00	29.90	48.71	0.04	0.03	0.04	n.d.	0.03	n.d.	n.d.	0.03	n.d.	n.d.	99.77

Table 6. (cont.)

<b>SULFIDES AND METALLIC PHASES</b>																	
<b>Elizabeth</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
01JH37core																	
Cu-Fe-S	15.71	0.00	0.00	0.00	27.17	56.21	0.02	0.00	0.00	0.00	0.07	0.01	n.d.	n.d.	n.d.	n.d.	99.21
FeS pyrrhotite	61.91	0.00	0.00	0.00	35.42	0.31	0.46	0.02	0.01	0.00	0.02	0.00	n.d.	n.d.	n.d.	n.d.	98.27
Cu-Fe-S	15.97	0.00	0.00	0.00	27.36	56.74	0.03	0.02	0.00	0.00	0.07	0.00	n.d.	n.d.	n.d.	n.d.	100.21
FeS pyrrhotite	62.05	0.00	0.01	0.00	35.68	0.28	0.38	0.02	0.00	0.00	0.00	0.02	n.d.	n.d.	n.d.	n.d.	98.54
bornite-digenite	4.97	0.00	0.01	0.00	23.10	73.21	0.01	0.00	0.03	0.00	0.06	0.00	n.d.	n.d.	n.d.	n.d.	101.37
bornite-digenite	4.67	0.00	0.03	0.00	22.76	73.94	0.01	0.03	0.03	0.00	0.06	0.00	n.d.	n.d.	n.d.	n.d.	101.52
Cu-Fe-S	17.12	0.00	0.01	0.00	28.22	55.39	0.02	0.00	0.00	0.00	0.03	0.00	n.d.	n.d.	n.d.	n.d.	100.81
bornite-digenite	8.82	0.00	0.00	0.00	24.48	68.36	0.01	0.01	0.01	0.00	0.05	0.00	n.d.	n.d.	n.d.	n.d.	101.74
<b>Ely</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
00JH34																	
FeS pyrrhotite	62.74	0.02	0.02	0.00	37.00	0.96	0.31	0.00	0.02	0.00	0.00	0.00	0.01	0.10	0.01	n.d.	101.28
Cu-Fe-S	17.05	0.00	0.00	0.00	31.53	52.14	0.03	0.04	0.03	0.00	0.05	0.00	0.00	0.05	0.00	n.d.	100.94
Cu-Fe-S	18.25	0.00	0.00	0.00	33.14	49.86	0.03	0.02	0.06	0.00	0.07	0.00	0.00	0.00	0.03	n.d.	101.48
FeS pyrrhotite	62.46	0.01	0.00	0.00	37.27	0.77	0.27	0.01	0.00	0.00	0.01	0.01	0.00	0.17	0.00	n.d.	101.08
FeS pyrrhotite	63.24	0.03	0.04	0.07	37.05	0.79	0.14	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.00	n.d.	101.51
FeS pyrrhotite	62.42	0.01	0.00	0.00	37.03	0.67	0.30	0.02	0.00	0.00	0.02	0.00	0.01	0.03	0.00	n.d.	100.61
Cu-Fe-S	18.16	0.00	0.01	0.00	30.93	51.32	0.02	0.04	0.04	0.00	0.02	0.00	0.00	0.00	0.00	n.d.	100.56
Cu-Fe-S	18.84	0.02	0.00	0.00	31.32	50.77	0.02	0.03	0.00	0.00	0.04	0.01	0.00	0.00	0.00	n.d.	101.08
FeS pyrrhotite	62.22	0.01	0.02	0.00	37.13	0.56	0.32	0.00	0.02	0.00	0.01	0.00	0.01	0.08	0.00	n.d.	100.49
Cu-Fe-S	14.23	0.00	0.02	0.00	28.45	57.12	0.01	0.01	0.06	0.00	0.02	0.00	0.00	0.00	0.00	n.d.	99.93
00JH38																	
FeS pyrrhotite	63.05	0.00	0.00	0.00	36.90	1.11	0.23	0.00	0.02	0.00	0.05	0.00	0.00	0.01	0.01	n.d.	101.50
Cu-Fe-S	16.76	0.01	0.00	0.00	29.44	55.02	0.01	0.03	0.01	0.00	0.10	0.00	0.00	0.00	0.18	n.d.	101.56
FeS pyrrhotite	62.05	0.00	0.03	0.00	35.52	1.17	0.18	0.02	0.00	0.00	0.06	0.02	0.00	0.00	0.06	n.d.	99.21
FeS pyrrhotite	60.87	0.01	0.00	0.02	37.45	2.83	0.33	0.04	0.01	0.00	0.03	0.00	0.00	0.07	0.00	n.d.	101.76
Cu-Fe-S	20.22	0.00	0.00	0.00	29.86	49.85	0.02	0.01	0.01	0.00	0.05	0.00	0.00	0.00	0.15	n.d.	100.20
Cu-Fe-S	13.52	0.00	0.00	0.00	27.53	59.53	0.63	0.03	0.00	0.00	0.10	0.00	0.00	0.00	0.06	n.d.	101.41
Cu-Fe-S	17.27	0.00	0.00	0.00	29.09	54.87	0.04	0.03	0.04	0.00	0.08	0.00	0.00	0.00	0.01	n.d.	101.46
FeS pyrrhotite	63.07	0.00	0.00	0.00	37.13	1.01	0.25	0.04	0.00	0.00	0.14	0.00	0.01	0.07	0.00	n.d.	101.83
01JH34a																	
Cu-Fe-S	23.88	0.01	0.00	0.00	31.97	43.08	0.04	0.02	0.00	0.00	0.08	0.00	n.d.	n.d.	n.d.	n.d.	99.11
Cu-Fe-S	28.36	0.01	0.01	0.00	32.40	36.67	0.05	0.06	0.03	0.00	1.51	0.00	n.d.	n.d.	n.d.	n.d.	99.13
Cu-Fe-S	19.57	0.01	0.00	0.00	28.58	51.82	0.04	0.06	0.00	0.00	0.06	0.00	n.d.	n.d.	n.d.	n.d.	100.17
Cu-Fe-S	14.83	0.00	0.00	0.00	27.96	55.33	0.04	0.00	0.00	0.00	0.07	0.01	n.d.	n.d.	n.d.	n.d.	98.24
Cu-Fe-S	14.83	0.00	0.00	n.d.	28.33	58.56	0.00	0.02	0.00	n.d.	0.15	n.d.	n.d.	0.00	0.00	0.33	102.23
Cu-Fe-S	14.43	0.00	0.00	n.d.	27.86	58.65	0.01	0.02	0.00	n.d.	0.10	n.d.	n.d.	0.00	0.00	0.69	101.78

Table 6. (cont.)

<b>SULFIDES AND METALLIC PHASES</b>																	
<b>Ely</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
<b>01JH34a (cont.)</b>																	
FeS pyrrhotite	61.45	0.01	0.01	0.00	35.25	2.02	0.46	0.02	0.04	n.d.	0.05	n.d.	n.d.	0.13	n.d.	n.d.	99.53
FeS pyrrhotite	63.29	0.00	0.01	0.00	35.52	0.75	0.47	0.01	0.01	n.d.	0.04	n.d.	n.d.	0.10	n.d.	n.d.	100.30
bornite-digenite	14.91	0.00	0.00	0.00	24.50	60.61	0.03	0.01	0.03	n.d.	0.05	n.d.	n.d.	0.00	n.d.	n.d.	100.16
bornite-digenite	14.76	0.00	0.00	0.00	24.09	60.84	0.03	0.00	0.00	n.d.	0.09	n.d.	n.d.	0.00	n.d.	n.d.	99.83
Cu-Fe-S	39.64	0.02	0.01	0.00	33.89	24.47	0.12	0.07	0.00	n.d.	0.36	n.d.	n.d.	0.03	n.d.	n.d.	98.67
FeS pyrrhotite	62.58	0.02	0.02	0.00	35.68	1.41	0.31	0.00	0.00	n.d.	0.00	n.d.	n.d.	0.07	n.d.	n.d.	100.21
Cu-Fe-S	36.95	0.00	0.02	0.00	33.99	27.45	0.09	0.03	0.02	n.d.	0.25	n.d.	n.d.	0.03	n.d.	n.d.	98.88
FeS pyrrhotite	60.21	0.00	0.01	0.00	35.12	3.62	0.23	0.00	0.00	n.d.	0.02	n.d.	n.d.	0.00	n.d.	n.d.	99.32
Cu-Fe-S	20.23	0.01	0.00	0.00	27.74	51.22	0.03	0.00	0.04	n.d.	0.05	n.d.	n.d.	0.02	n.d.	n.d.	99.36
<b>Ducktown</b>																	
<b>01CB25</b>																	
bornite-digenite	8.70	0.03	0.00	0.00	16.33	60.56	0.03	0.04	0.00	0.00	0.16	0.01	0.00	0.00	0.00	n.d.	85.85
Cu-Fe-S	30.41	0.09	0.00	n.d.	20.59	23.29	0.05	0.02	0.00	n.d.	0.56	n.d.	n.d.	0.00	n.d.	n.d.	75.06
Cu-Fe-S	40.20	0.11	0.00	n.d.	25.89	20.15	0.05	0.02	0.01	n.d.	0.90	n.d.	n.d.	0.02	n.d.	n.d.	87.40
Cu-Fe-S	39.36	0.08	0.00	n.d.	25.07	22.05	0.05	0.00	0.01	n.d.	0.92	n.d.	n.d.	0.02	n.d.	n.d.	87.63
Cu-Fe-S	35.34	0.10	0.00	n.d.	26.39	24.03	0.05	0.00	0.08	n.d.	0.89	n.d.	n.d.	0.00	n.d.	n.d.	86.94
Cu-Fe-S	43.60	0.10	0.00	n.d.	25.14	16.54	0.03	0.01	0.00	n.d.	0.99	n.d.	n.d.	0.00	0.37	6.46	93.31
Cu-Fe-S	52.30	0.19	0.00	n.d.	25.95	9.41	0.03	0.00	0.00	n.d.	1.13	n.d.	n.d.	0.00	0.22	7.00	96.32
FeS pyrrhotite	53.12	0.21	0.00	n.d.	25.62	5.03	0.05	0.00	0.00	n.d.	1.46	n.d.	n.d.	0.00	0.60	7.65	93.83
Cu-Fe-S	42.12	0.13	0.01	n.d.	24.98	18.64	0.05	0.02	0.00	n.d.	1.06	n.d.	n.d.	0.00	0.31	5.97	93.36
Cu-Fe-S	43.09	0.11	0.00	n.d.	26.09	19.33	0.03	0.01	0.00	n.d.	1.12	n.d.	n.d.	0.00	0.16	6.00	96.02
Cu-Fe-S	49.54	0.21	0.01	n.d.	24.73	11.43	0.05	0.01	0.00	n.d.	1.28	n.d.	n.d.	0.02	0.39	6.98	94.72
Cu-Fe-S	38.14	0.13	0.00	n.d.	25.73	19.39	0.06	0.01	0.00	n.d.	1.29	n.d.	n.d.	0.00	0.26	6.25	91.33
Cu-Fe-S	50.16	0.15	0.00	n.d.	28.73	12.39	0.03	0.00	0.00	n.d.	1.25	n.d.	n.d.	0.03	0.22	5.43	98.48
Cu-Fe-S	52.48	0.18	0.01	n.d.	28.01	10.80	0.06	0.02	0.00	n.d.	1.38	n.d.	n.d.	0.00	0.28	6.53	99.83
Cu-Fe-S	28.28	0.09	0.00	n.d.	13.74	44.54	0.02	0.00	0.00	n.d.	0.67	n.d.	n.d.	0.01	0.18	6.53	94.10
FeS pyrrhotite	61.00	0.16	0.00	n.d.	23.89	3.37	0.04	0.00	0.00	n.d.	0.76	n.d.	n.d.	0.00	0.47	9.70	99.50
Cu-Fe-S	44.76	0.16	0.00	n.d.	29.10	18.79	0.04	0.01	0.00	n.d.	1.19	n.d.	n.d.	0.04	0.24	5.81	100.22
Cu-Fe-S	45.62	0.15	0.01	n.d.	28.93	17.59	0.03	0.02	0.00	n.d.	1.15	n.d.	n.d.	0.01	0.17	5.54	99.29
Cu-Fe-S	46.13	0.15	0.00	n.d.	25.87	18.37	0.06	0.00	0.00	n.d.	1.24	n.d.	n.d.	0.00	0.25	6.42	98.57
Cu-Fe-S	52.72	0.18	0.00	n.d.	24.22	10.22	0.07	0.02	0.00	n.d.	1.49	n.d.	n.d.	0.00	0.61	8.70	98.31
Cu-Fe-S	51.29	0.16	0.00	n.d.	25.17	13.79	0.05	0.00	0.00	n.d.	1.17	n.d.	n.d.	0.03	0.38	7.58	99.72
Cu-Fe-S	51.21	0.16	0.00	n.d.	25.22	13.06	0.03	0.00	0.00	n.d.	1.28	n.d.	n.d.	0.00	0.45	7.35	98.85
Cu-Fe-S	51.75	0.16	0.01	n.d.	25.20	13.17	0.02	0.00	0.00	n.d.	1.31	n.d.	n.d.	0.00	0.54	7.66	99.90
Cu-Fe-S	50.82	0.17	0.00	n.d.	27.86	11.89	0.05	0.00	0.00	n.d.	1.45	n.d.	n.d.	0.01	0.30	6.62	99.27
Cu-Fe-S	55.97	0.21	0.00	n.d.	23.39	7.24	0.05	0.00	0.00	n.d.	1.40	n.d.	n.d.	0.01	0.88	9.25	98.49

Table 6. (cont.)

**SULFIDES AND METALLIC PHASES**

<b>Ducktown</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
01CB25 (cont.)																	
Cu-Fe-S	47.57	0.17	0.00	n.d.	22.77	13.30	0.05	0.01	0.00	n.d.	1.58	n.d.	n.d.	0.01	0.81	9.89	96.23
Cu-Fe-S	49.31	0.15	0.00	0.00	27.84	13.13	0.04	0.01	0.01	n.d.	1.10	n.d.	n.d.	0.00	0.28	n.d.	91.95
Cu-Fe-S	40.38	0.13	0.00	0.01	26.91	22.64	0.05	0.00	0.01	n.d.	1.14	n.d.	n.d.	0.00	0.34	n.d.	91.67
Cu-Fe-S	42.00	0.11	0.00	0.00	27.56	21.68	0.05	0.00	0.02	n.d.	1.12	n.d.	n.d.	0.02	0.18	n.d.	92.83
Cu-Fe-S	39.11	0.07	0.00	0.00	30.56	25.00	0.07	0.01	0.01	n.d.	0.93	n.d.	n.d.	0.08	0.08	n.d.	95.98
Cu-Fe-S	46.48	0.15	0.00	0.00	25.06	18.88	0.07	0.00	0.02	n.d.	1.14	n.d.	n.d.	0.06	0.35	n.d.	92.28
Cu-Fe-S	41.33	0.13	0.00	0.03	22.77	28.38	0.05	0.03	0.00	n.d.	1.02	n.d.	n.d.	0.00	0.27	n.d.	94.09
Cu-Fe-S	41.13	0.14	0.00	0.01	22.83	28.21	0.06	0.01	0.05	n.d.	1.05	n.d.	n.d.	0.01	0.28	n.d.	93.83
<b>Clayton</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
53JH00																	
Sb (As,Pb)	0.00	0.01	5.48	4.84	0.00	0.05	0.02	0.12	0.00	n.d.	0.05	88.22	0.00	0.00	0.00	n.d.	98.78
Sb (As,Pb)	0.00	0.00	3.73	18.58	0.67	0.56	0.01	0.10	0.00	n.d.	0.00	74.10	0.78	0.00	0.00	n.d.	98.52
Cu	0.49	0.00	0.01	0.06	0.76	100.53	0.00	0.00	0.06	0.00	0.08	0.03	n.d.	n.d.	n.d.	n.d.	102.02
Pb (Sb)	0.06	0.01	0.00	92.61	0.00	0.00	0.00	0.02	0.00	n.d.	0.00	2.37	0.01	0.01	0.00	n.d.	95.08
Pb (Sb)	0.09	0.00	0.00	91.82	0.00	0.02	0.00	0.00	0.00	n.d.	0.01	2.37	0.00	0.00	0.00	n.d.	94.30
Pb (Sb)	0.09	0.00	0.00	90.32	0.00	0.32	0.01	0.00	0.00	n.d.	0.00	2.68	0.00	0.02	0.00	n.d.	93.43
Pb (Sb)	0.00	0.00	0.00	90.29	0.00	0.12	0.03	0.00	0.00	n.d.	0.02	2.68	0.00	0.02	0.00	n.d.	93.16
Pb	0.00	0.00	0.01	91.06	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.63	0.00	0.00	0.00	n.d.	91.71
PbS	0.22	0.00	0.02	83.51	13.04	0.47	0.00	0.00	0.00	0.00	0.03	0.01	n.d.	n.d.	n.d.	n.d.	97.30
PbS	0.08	0.01	0.00	83.51	13.27	4.99	0.00	0.01	0.00	n.d.	0.01	0.07	0.00	0.01	0.00	n.d.	101.95
PbS	0.00	0.00	0.06	82.79	13.19	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	n.d.	97.22
PbS	0.04	0.01	0.00	82.33	11.56	4.03	0.00	0.04	0.00	n.d.	0.02	0.72	0.00	0.00	0.00	n.d.	98.75
PbS	0.08	0.00	0.00	82.06	13.21	4.28	0.00	0.00	0.00	n.d.	0.04	0.07	0.05	0.00	0.00	n.d.	99.78
PbS	0.58	0.01	0.02	81.71	13.85	6.71	0.00	0.00	0.00	0.00	0.02	0.00	0.19	0.00	0.00	n.d.	103.08
PbS	0.20	0.01	0.00	80.46	13.51	7.78	0.01	0.01	0.00	0.00	0.03	0.00	n.d.	n.d.	n.d.	n.d.	102.00
PbS	1.87	0.06	0.00	75.11	12.75	5.85	0.00	0.00	0.22	0.00	0.37	0.05	n.d.	n.d.	n.d.	n.d.	96.28
PbCuS	1.61	0.00	0.00	76.09	14.78	10.75	0.00	0.00	0.00	n.d.	0.29	0.00	0.00	0.04	0.00	n.d.	103.58
PbCuS	2.03	0.02	0.00	72.56	14.95	12.60	0.00	0.01	0.00	n.d.	0.06	0.00	0.02	0.04	0.00	n.d.	102.29
PbCuS	0.48	0.01	0.20	61.18	14.13	24.31	0.00	0.00	0.01	n.d.	0.06	3.04	0.09	0.00	0.00	n.d.	103.50
PbCuS	1.49	0.00	0.00	49.04	16.91	36.78	0.00	0.01	0.00	n.d.	0.07	0.00	0.04	0.00	0.00	n.d.	104.33
(Cu, Ag) <sub>6</sub> PbS <sub>4</sub> furutobeite	1.96	0.00	0.06	27.47	18.59	54.42	0.01	0.00	0.00	n.d.	0.09	0.00	0.05	0.00	0.00	n.d.	102.64
FeAs(Cu)	43.41	0.00	51.50	0.14	0.33	1.46	0.10	0.10	0.02	n.d.	0.04	0.43	0.00	0.25	0.00	n.d.	97.86
FeAs(Cu)	42.66	0.00	53.30	0.05	0.18	2.44	0.25	0.08	0.01	n.d.	0.00	0.56	0.00	0.71	0.00	n.d.	100.31
FeAs(Cu)	42.58	0.00	51.69	0.13	0.13	2.57	0.01	0.05	0.09	n.d.	0.11	1.66	0.00	0.75	0.00	n.d.	99.84
FeAs(Cu)	42.22	0.00	52.10	0.42	0.18	0.70	0.01	0.10	0.01	n.d.	0.07	0.66	0.00	0.73	0.00	n.d.	97.28



Table 6. (cont.)

**SULFIDES AND METALLIC PHASES**

<b>Clayton</b>	Fe	Mn	As	Pb	S	Cu	Co	Se	Ag	Cd	Zn	Sb	Sn	Ni	Si	O	Total
53JH00 (cont.)																	
FeAs(Cu)	42.21	0.00	52.27	2.12	0.27	0.97	0.21	0.02	0.01	n.d.	0.04	0.46	0.00	0.42	0.00	n.d.	99.06
AsFe(CuSb)	38.25	0.00	51.79	0.10	0.08	7.00	0.21	0.04	0.10	n.d.	0.02	4.20	0.00	0.60	0.00	n.d.	102.46
AsFe(CuSb)	37.88	0.00	51.35	0.24	0.20	6.99	0.24	0.03	0.20	n.d.	0.01	5.40	0.00	0.68	0.00	n.d.	103.26
AsFe(PbSb)	38.57	0.00	47.93	9.33	0.15	0.73	0.23	0.04	0.01	n.d.	0.01	1.70	0.00	0.59	0.00	n.d.	99.37
AsFe(PbSb)	29.33	0.00	60.74	1.82	0.25	1.16	0.06	0.08	0.49	n.d.	0.47	3.16	0.00	1.72	0.00	n.d.	99.34
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.33	0.01	0.19	0.23	0.04	51.59	0.01	0.07	0.90	n.d.	0.06	49.23	0.27	0.09	0.00	n.d.	102.99
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.39	0.00	0.20	1.80	0.10	50.00	0.01	0.02	0.56	n.d.	0.04	48.48	0.28	0.00	0.00	n.d.	101.87
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.11	0.00	1.31	0.42	0.05	50.25	0.00	0.03	0.99	n.d.	0.04	47.32	0.22	0.13	0.00	n.d.	100.87
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.20	0.00	1.50	0.15	0.03	50.83	0.00	0.06	0.97	n.d.	0.06	47.32	0.00	0.00	0.00	n.d.	101.12
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.15	0.01	2.70	0.11	0.03	52.25	0.00	0.03	1.12	n.d.	0.09	45.74	0.21	0.01	0.00	n.d.	102.43
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.04	0.00	2.40	0.21	0.04	51.76	0.00	0.09	1.03	n.d.	0.08	45.52	0.00	0.05	0.00	n.d.	101.22
Cu <sub>2</sub> (Sb,Tl) cuprostibite	0.01	0.00	2.39	0.13	0.00	52.51	0.01	0.05	0.93	0.00	0.04	43.46	n.d.	n.d.	n.d.	n.d.	99.54
CuAsSb	0.03	0.01	5.11	4.32	0.02	15.75	0.00	0.11	0.02	n.d.	0.01	75.00	0.69	0.00	0.00	n.d.	101.07
Cu <sub>3</sub> As domeykite	0.00	0.00	23.65	0.90	0.09	69.86	0.00	0.00	0.09	n.d.	0.09	5.49	0.01	0.00	0.00	n.d.	100.18
Cu <sub>3</sub> As domeykite	0.00	0.01	24.79	0.17	0.04	69.53	0.00	0.09	0.04	n.d.	0.07	3.44	0.00	0.00	0.00	n.d.	98.16
Cu <sub>3</sub> As domeykite	0.05	0.01	25.40	0.07	0.00	72.74	0.00	0.11	0.07	n.d.	0.07	3.24	0.03	0.02	0.00	n.d.	101.82
Ag <sub>3</sub> Sb dyscrasite	0.00	0.01	0.03	0.11	0.01	0.22	0.00	0.03	72.46	n.d.	0.00	26.10	0.11	0.00	0.00	n.d.	99.09
ZnCuFeS	15.81	0.18	6.42	0.90	28.01	10.24	0.02	0.00	0.02	n.d.	33.68	0.21	0.00	0.09	0.00	n.d.	95.59
ZnCuFeS	14.52	0.16	0.31	0.00	30.91	19.57	0.02	0.00	0.00	n.d.	31.18	0.00	0.00	0.00	0.01	n.d.	96.68
CuFeS	14.83	0.02	0.17	0.00	27.40	55.95	0.01	0.02	0.46	0.00	0.07	0.00	n.d.	n.d.	n.d.	n.d.	98.94
CuFeS	11.51	0.03	0.17	0.13	25.23	62.74	0.01	0.03	0.02	n.d.	0.06	0.02	0.00	0.00	0.00	n.d.	99.96
CuFeS	11.26	0.03	0.26	0.16	25.47	63.13	0.01	0.00	0.01	n.d.	0.08	0.03	0.00	0.00	0.01	n.d.	100.45
CuFeS	10.96	0.03	0.23	0.10	24.91	62.36	0.00	0.00	0.01	n.d.	0.07	0.02	0.00	0.02	0.00	n.d.	98.71
CuFeS	10.04	0.01	0.10	0.04	24.61	66.97	0.02	0.00	0.01	0.00	0.07	0.01	0.00	0.00	0.00	n.d.	101.87
CuFeS	9.94	0.00	0.22	0.00	24.31	66.77	0.01	0.04	0.00	0.00	0.09	0.02	n.d.	n.d.	n.d.	n.d.	101.40
CuFeS	8.78	0.00	0.09	13.42	23.36	54.73	0.02	0.03	0.02	n.d.	0.10	0.00	0.05	0.00	0.00	n.d.	100.59
CuFeS	7.26	0.02	0.03	10.03	21.00	60.30	0.01	0.04	0.00	n.d.	0.23	0.35	0.00	0.02	0.00	n.d.	99.29

<sup>a</sup> If Fe is 6.7 wt. % or greater, the concentration of Co was corrected for Fe-Co overlap using equation  $Co_{(corrected)} = Co_{(original)} - (0.002 * Fe - 0.0133)$  (Harvey Belkin, personal communication, 2003).

<sup>b</sup> not determined

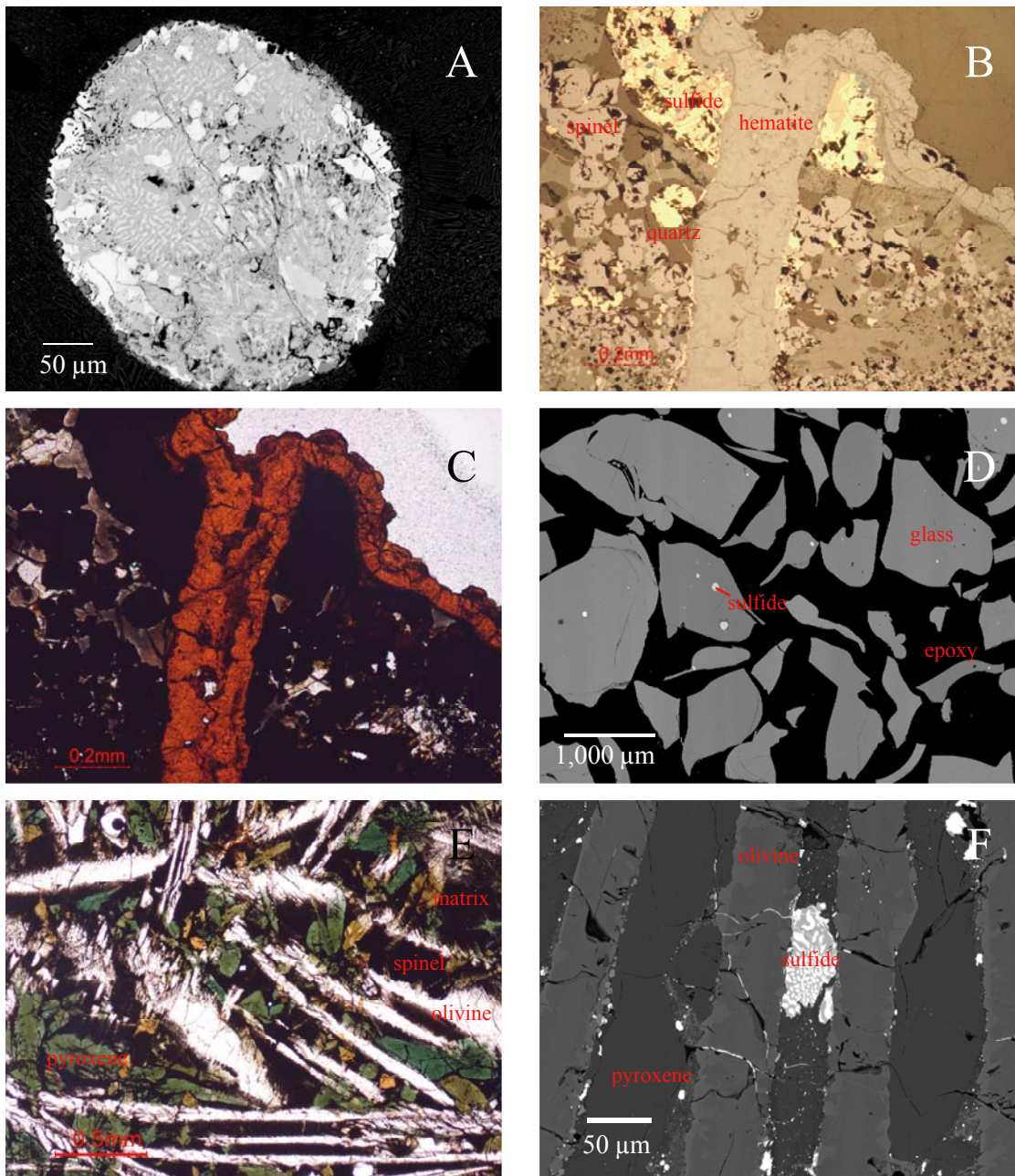


Figure 9. Photomicrographs of slag and sintered waste rock. A. Backscattered scanning electron (BSE) photomicrograph of 01JH28 (Elizabeth) illustrating small-scale exsolution in sulfide blebs. B. Reflected light and C. transmitted light photomicrographs of 01JH31A (Ely). D. BSE photomicrograph of granulated slag 01CB25 (Ducktown) in epoxy (black background). E. Transmitted light and F. BSE photomicrographs of 53JH00 (Clayton).

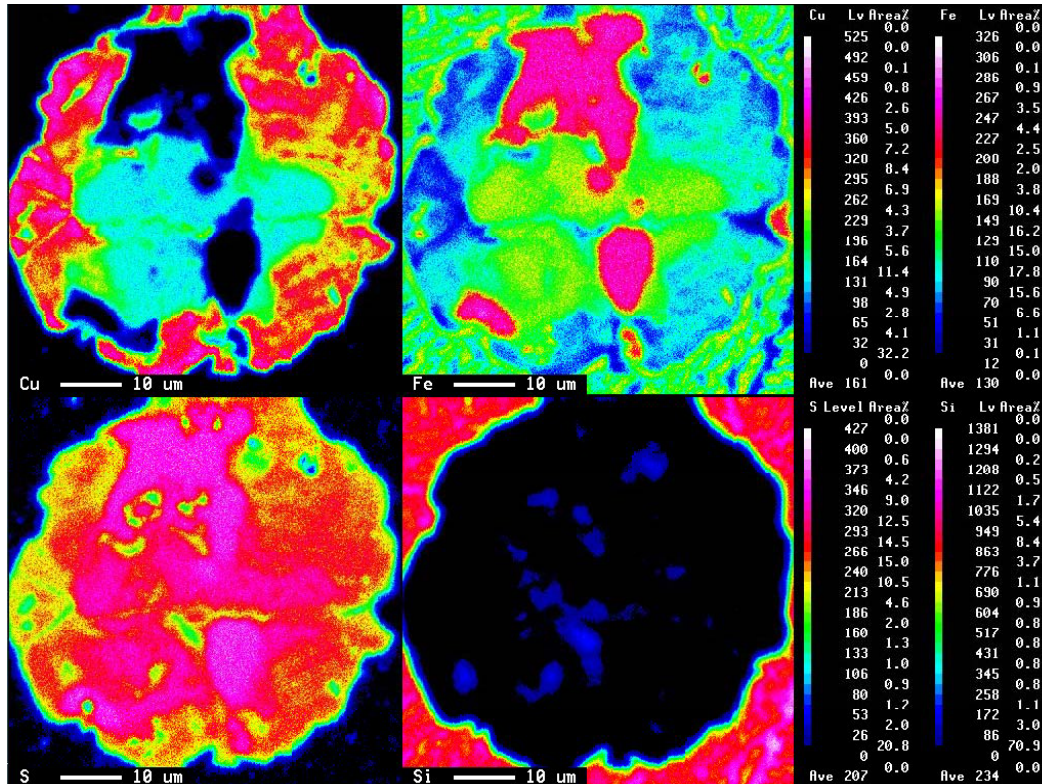


Figure 10. Electron-microprobe map illustrating the distribution of Cu, Fe, S, and Si in a sulfide bleb in sample 01JH34b slag from the Ely mine. Warmer colors indicate higher concentrations; cooler colors indicate lower concentrations.

### Sintered waste rock

Two samples of sintered waste rock collected from the Elizabeth mine are oxidized red sinter (98JHNP-B-RS) composed of hematite, jarosite, spinel, quartz, plagioclase, and minor mica, and black sintered roasted ore (98JHNPB-s) composed of hematite, jarosite, quartz, and minor mica. One sample of sintered waste rock was collected from the Ely mine. This sample was divided into two splits based on textural variations, 01JH31A being vesicular. Both 01JH31A and 01JH31B contain hematite, spinel, sulfide, plagioclase and quartz. However, the amount of quartz in sample 01JH31B is especially high as reflected by the high concentration of SiO<sub>2</sub> (55.97 wt. %) in the bulk chemical analysis. Photomicrographs of sample 01JH31A (Figure 9B and C) in reflected and transmitted light illustrate hematite, sulfide, spinel, and quartz.

### Ducktown mining district

#### Granulated slag

The granulated slag consists of conchoidally fractured bits of material less than a centimeter in diameter (Figure 9D). The sample contains glass, Fe-Cu sulfides, metallic

phases, and rare hematite. The composition of the glass is dominated by Fe and Si with minor Al (up to 4.11 wt. %  $\text{Al}_2\text{O}_3$ ), Ca (up to 5.93 wt. %  $\text{CaO}$ ), and S (up to 5.60 wt. %  $\text{SO}_3$ ) (Figure 5 and Table 4). The compositions of the sulfides (Table 6) are intermediate between discrete phases in the Cu-Fe-S system and generally contain  $\text{Fe} > \text{Cu}$ . The sulfides contain an average of 1.11 wt. % Zn and are up to 300  $\mu\text{m}$  in diameter. Sulfide blebs locally contain micrometer-size inclusions and veinlets of native metals, such as Ni, and inclusions of glass or quartz (Figure 11). The low analytical totals from electron-microprobe analyses may be partially due to the tiny inclusions of glass or quartz. Many sulfides were analyzed for oxygen using the electron microprobe. The sulfides contained up to 9.89 wt. % O suggesting the low totals may also be related to the presence of oxides. The sulfides display small-scale exsolution, which is similar to the Vermont samples (Figure 12).

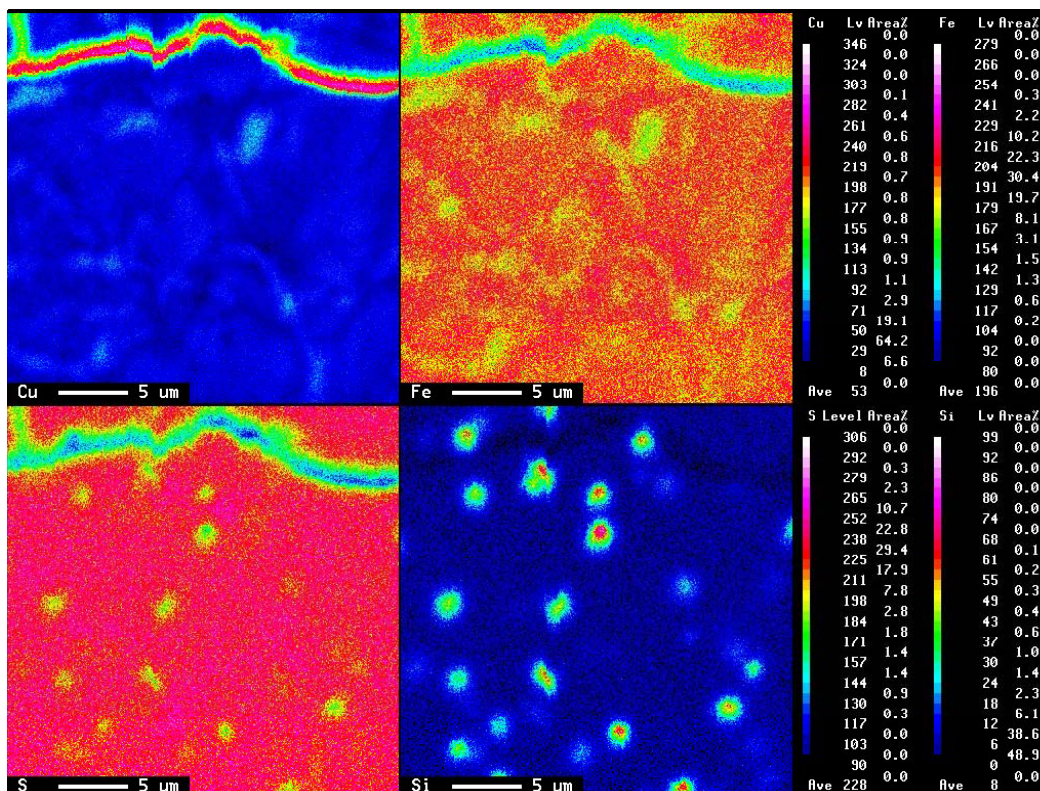


Figure 11. Electron-microprobe map illustrating the distribution of Cu, Fe, S, and Si in a sulfide bleb in granulated slag sample 01CB25 from Ducktown. Warmer colors indicate higher concentrations; cooler colors indicate lower concentrations.

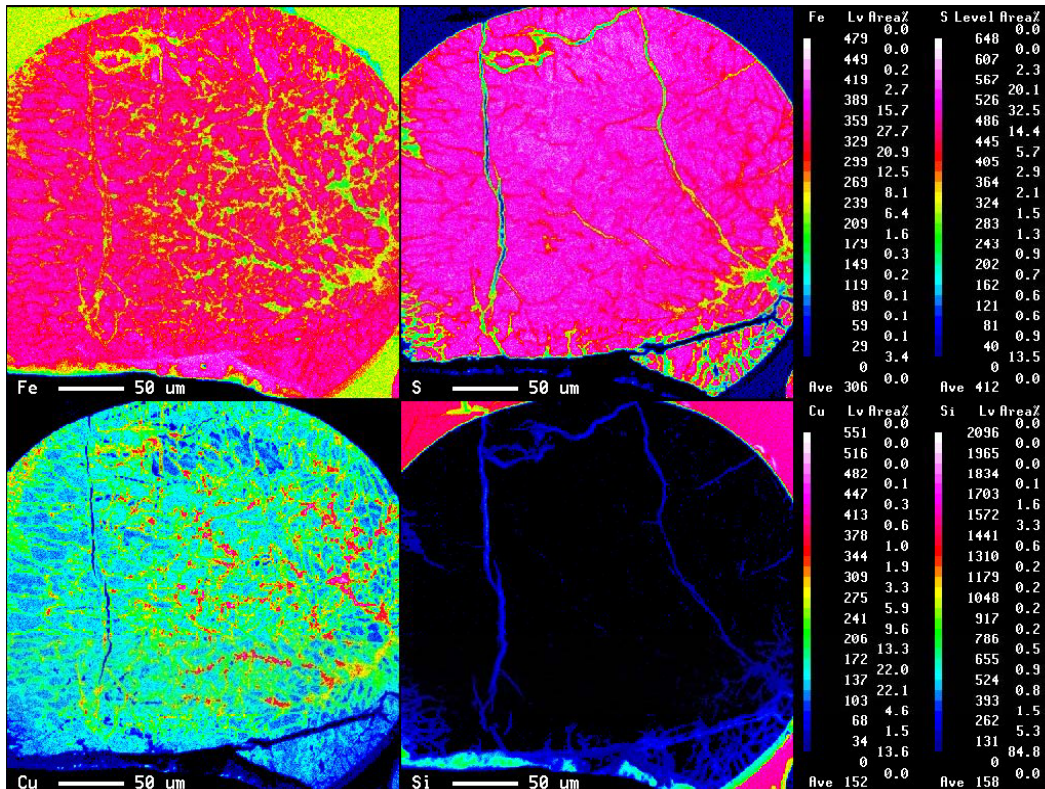


Figure 12. Electron-microprobe map illustrating the distribution of Fe, S, Cu and Si in a sulfide bleb in granulated slag sample 01CB25 from Ducktown. Warmer colors indicate higher concentrations; cooler colors indicate lower concentrations.

### Calcine

The calcine sample from the Ducktown mining district is dark red and composed of silt-sized grains (Figure 2D). The sample is mainly hematite, with lesser quartz, spinel, sulfides, gypsum, and minor chlorite and biotite. The hematite is highly porous and occurs as rounded to sub-angular fragments ranging from a few micrometers to 100 µm in diameter.

### Clayton smelter site

The air-cooled slag from the Clayton smelter site is texturally similar to the Vermont copper belt slag. Both display flow textures, and have glassy chilled margins containing vesicles, and coarse-grained crystalline interiors. The phases present are olivine, pyroxene, glass, spinel, sulfides, alloys, and native metals. The olivine crystals are commonly randomly oriented laths up to several centimeters long (Figure 9E and F). The composition of the olivines (Figure 7) falls between fayalite and kirschsteinite based on electron-microprobe analyses (Table 3). The olivine-group minerals also contain minor Mn (up to 3.32 wt. % MnO), Mg (up to 2.72 wt. % MgO) and Zn (up to 1.25 wt. %

ZnO). Several of the laths are zoned with the interior being slightly enriched in Ca and Mg (Table 3). The subhedral pyroxenes are shown in Figure 9E and F. Pyroxene is hedenbergitic in composition and contains an average of 6.64 wt. %  $\text{Al}_2\text{O}_3$ , 0.83 wt. % MnO, and 0.70 wt. % ZnO (Figure 13 and Table 3).

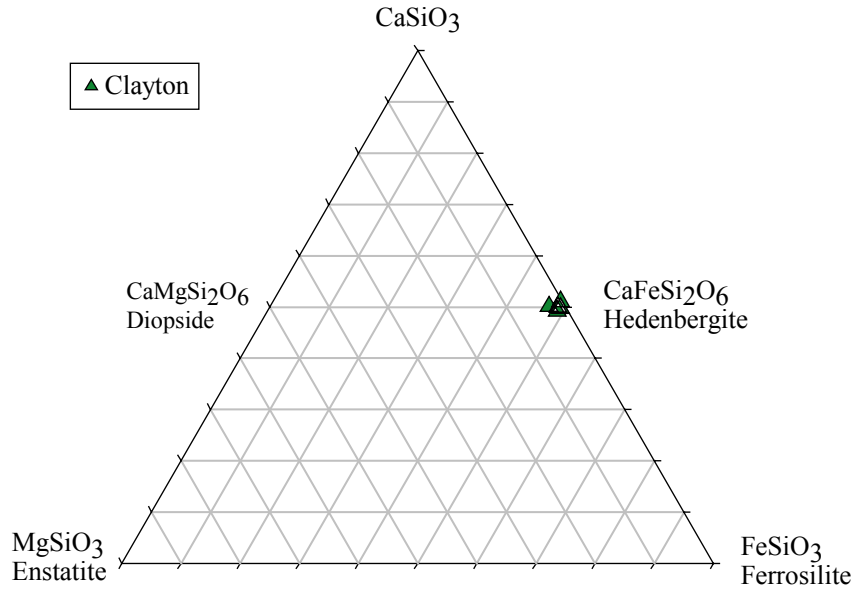


Figure 13. Composition of pyroxene in Clayton smelter slag on a  $\text{MgSiO}_3$ - $\text{FeSiO}_3$ - $\text{CaSiO}_3$  ternary diagram.

The glass phase in the Clayton smelter slag is interstitial and the composition can be characterized as  $\text{SiO}_2 > \text{FeO} \geq \text{CaO} > \text{Al}_2\text{O}_3$  (Figure 5 and Table 4). The composition of interstitial glass in the Clayton smelter slag is similar to the composition of interstitial glass in the slag from the Vermont copper belt samples, although it contains higher concentrations of Ca and lower concentrations of Al (Figure 5). The interstitial glass also contains minor Pb (average 4.26 wt. % PbO) and Zn (average 3.19 wt. % ZnO).

Subhedral to euhedral spinel up to 50  $\mu\text{m}$  in diameter is found in the Clayton smelter slag (Figure 9E). The composition of spinel (Table 5 and Figure 8) is magnetite with up to 3.27 wt. %  $\text{Al}_2\text{O}_3$ . The spinels also contain ZnO (average 1.31 wt. %) and  $\text{TiO}_2$  (average 1.02 wt. %).

The sulfide minerals bornite-digenite, galena, and sphalerite/wurtzite  $[(\text{Fe}, \text{Zn})\text{S}]$  occur either as discrete grains or as admixtures with metallic phases such as Sb, Cu, Pb, and alloys of various metals including Pb, Sb, Cu, Fe, As, and Ag (Table 6). Metallic Pb and sphalerite/wurtzite were identified qualitatively using SEM. These admixtures are up to several hundred micrometers in diameter and display myrmekitic textures and micrometer-scale exsolution features (Figure 9F, and Figure 14). Figure 14 illustrates the composition of a detailed section of one of these complex polymineralic blebs. Because of the fine-grained exsolved nature of the material, analyses may represent admixtures of phases.

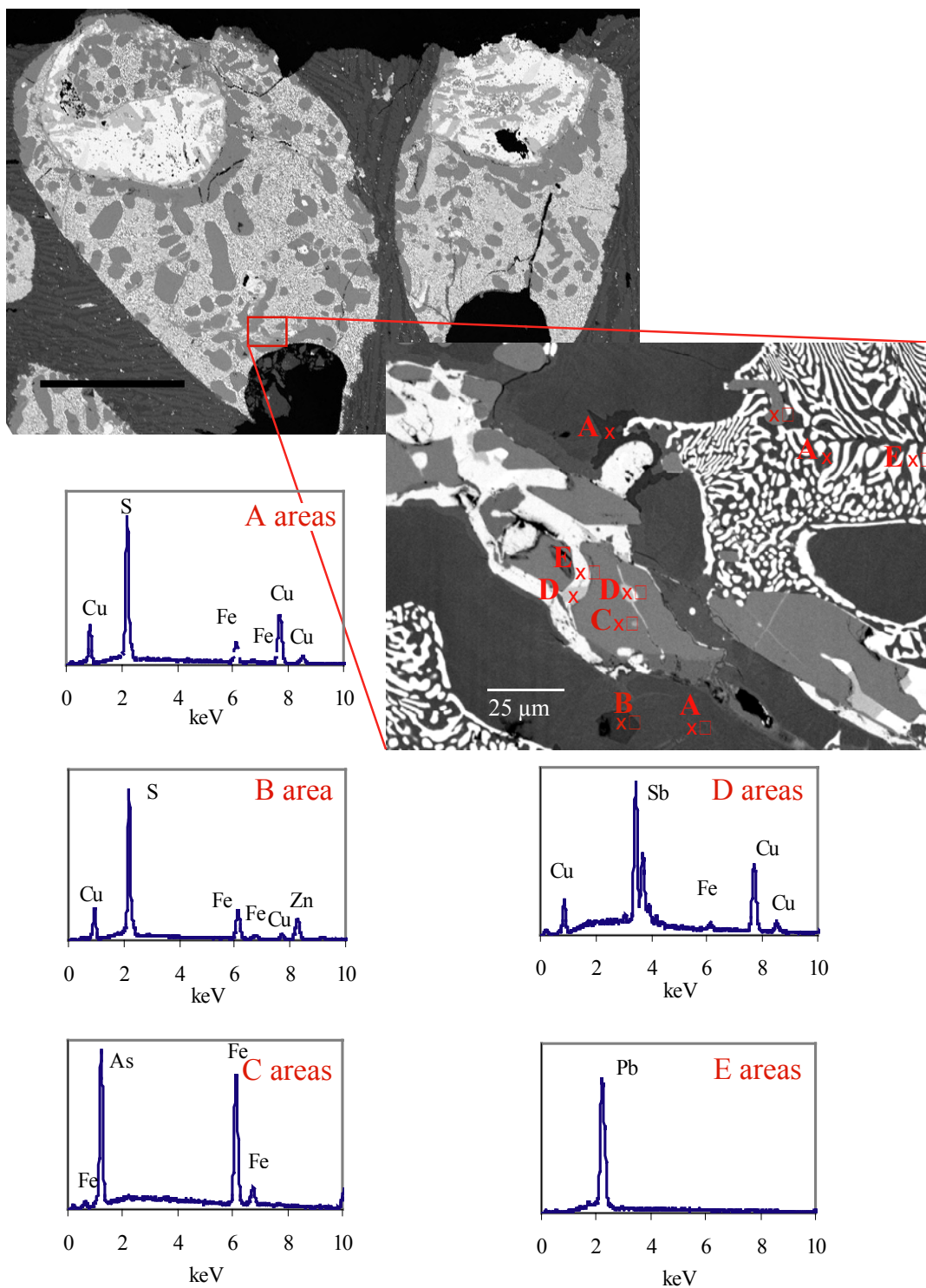


Figure 14. Backscatter scanning electron photomicrographs of a large polyminerallitic particle in the Clayton smelter slag (sample 53JH00). The energy-dispersive spectra shown are for areas outlined in the close-up view of larger blebs.

## Secondary Mineralogy

The slag and other waste rock historically have been and currently are subjected to weathering. The reactivity of this material is evident in the formation of secondary minerals on these samples. Samples from a slag pile at the Ely mine contain crystalline and amorphous secondary mineral and include chalcantite (Figure 15A and B), rozenite, siderotil, jarosite, brochantite, gypsum, and amorphous Fe and Al hydroxides. Minerals such as jarosite, gypsum, and amorphous Al and Fe coatings are shown on this same slag pile at the Ely mine in Figure 15C. Secondary mineral growths were also seen on the granulated slag pile at Ducktown and the weathered surface consists of jarosite and gypsum as shown in Figure 15D.

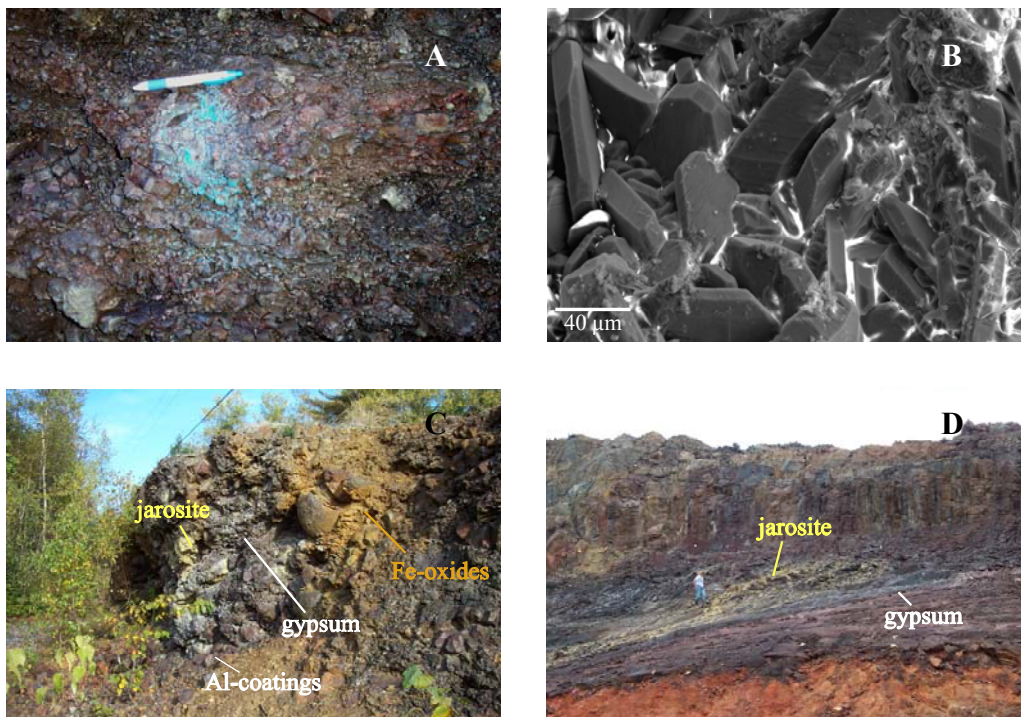


Figure 15. Photographs and a photomicrograph illustrating secondary mineral growths on pot slag at the Ely mine and granulated slag at Ducktown. A. Outcrop of pot slag at the Ely mine, showing surficial growths of chalcantite (blue salt). B. Backscatter scanning electron photomicrograph of chalcantite crystals. C. Weathered surface of Ely slag showing jarosite, gypsum, Fe-oxides, and Al-coatings. Note pot casts. D. Weathered surface of granulated slag at Ducktown showing jarosite and gypsum.

## LEACHATE DATA

Leaching tests conducted on crushed splits (<2 mm in diameter) with deionized water (DIW) and eastern synthetic precipitation (ESP) indicate that significant concentrations of metals can be released from the slag and waste rock. The



concentrations of most major elements in the DIW leachate and ESP leachate are similar except for Al, which is leached more readily by ESP than by DIW for most samples. In general, the concentration of trace elements in leachate produced by ESP (pH=4.1) is equal to or higher than those in leachate produced by deionized water (pH=5.0) (Table 7). For example, the concentration of Cu in DIW leachate is the same as in the ESP leachate for the calcine sample from Ducktown (01CB23) using the ICP-MS data. Whereas, the concentration of Cu in DIW leachate is less than half of that in the ESP leachate for the slag sample 01JH28rind from the Elizabeth mine. The final pH of the DIW leachate is higher than that of the ESP leachate for all samples except for 98JHNPB-s, 01JH28core, and 53JH00. Also, the specific conductance of all samples (except 01JH27) is lower in leachate produced by DIW than in leachate produced by ESP.

The major anion in the leachate for all samples is sulfate. The cations are dominated by Si, Ca, K, Na, and Mg; Al, Fe, and Cu are significant in a few samples. The highest concentration of Ca (180 mg/L) is found in leachate from the Ducktown calcine, whereas the highest concentration of Fe (60 mg/L) is found in leachate from the Ely sintered waste rock (Table 7). The concentrations of trace elements in the leachates vary from sample to sample as illustrated in Figure 16. For example, the concentrations of Cu range from 19 to 21,000 µg/L. All of the concentrations of Cu in leachate are greater than the chronic and acute water-quality guidelines for the protection of aquatic life (assuming a hardness of 100 mg/L CaCO<sub>3</sub>) as shown in Figure 16A (U.S. E.P.A., 1993). The highest concentration of Cu is found in leachate from waste rock (sample 01JH31B from the Ely mine). This sample also contains the second highest concentration of Cu (11,500 mg/kg) in the bulk chemical analysis. The concentration of Zn in the leachate (Figure 16B) in most samples is higher than the acute and chronic toxicity guidelines for the protection of aquatic life. The highest concentration of Zn (3,900 mg/L) in leachate from the Ducktown calcine (01CB23) is nearly an order of magnitude greater than the concentration of Zn in the other leachates. There is no U.S. E.P.A. toxicity guideline established for Co, but the concentration of Co in many leachates exceeds the New York water criterion (Figure 16C). Also, the concentrations of Cd and Fe in many leachates are higher than the chronic toxicity guidelines for aquatic life (Figure 16D and E). In contrast, the concentrations of Pb and Ni are not significant for most samples (Figure 16F and G). However, the concentration of Pb in the leachate from the Clayton smelter slag exceeds water-quality guidelines for the protection of aquatic life by several orders of magnitude. The leachate from this slag also contains the highest concentrations of As (52 µg/L), Ba (5.8 µg/L), Mn (140 µg/L), and Sb (290 µg/L).

Table 7. Analytical results of leaching tests. See Crock and others (1999) for explanation of methods.

parameter/element	leachate solution <sup>a</sup>	spec. cond.	pH	alkalinity	Ag	Ag	Al	Al	As	As	Au	B		
method				Gran titration	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-AES		
units		µS/cm		mg/L CaCO <sub>3</sub>	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L		
	site	sample												
<b>Elizabeth</b> □		98JHNP-B-RS	DIW	63.4	4.19	n.d. <sup>b</sup>	<1	<0.01	0.18	150	<100	0.4	<0.01	66
		98JHNP-B-RS	ESP	82.3	4.05	n.d.	<1	<0.01	0.3	240	<100	0.3	<0.01	60
		98JHNB-s	DIW	144.3	3.56	n.d.	<1	<0.01	0.59	460	<100	0.3	<0.01	43
		98JHNB-s	ESP	164.2	3.56	n.d.	<1	<0.01	0.66	540	<100	<0.2	<0.01	31
		00JH05	DIW	30.6	4.83	n.d.	<1	<0.01	0.051	50	<100	0.2	<0.01	72
		00JH05	ESP	35.6	4.56	n.d.	<1	<0.01	0.1	88	<100	<0.2	<0.01	56
		01JH27	DIW	88.5	4.60	0.19	<1	<0.01	0.056	53	<100	0.3	<0.01	60
		01JH27	ESP	73.0	4.16	0.30	<1	<0.01	0.12	99	<100	0.3	<0.01	55
		01JH27Dup	DIW	78.8	4.71	n.d.	<1	<0.01	0.042	44	<100	0.3	<0.01	56
		01JH27Dup	ESP	83.0	4.30	n.d.	<1	<0.01	0.11	95	<100	<0.2	<0.01	54
		01JH28	DIW	21.7	5.16	2.72	<1	<0.01	<0.01	6.9	<100	0.3	<0.01	58
		01JH28	ESP	27.2	4.95	2.22	<1	<0.01	0.02	27	<100	0.2	<0.01	43
		01JH28core	DIW	6.6	5.23	2.82	<1	0.01	<0.01	4.4	<100	<0.2	<0.01	66
		01JH28core	ESP	7.9	5.45	1.87	<1	<0.01	<0.01	3.1	<100	<0.2	<0.01	61
		01JH28rind	DIW	7.4	5.50	4.05	<1	0.01	<0.01	3.2	<100	<0.2	<0.01	73
		01JH28rind	ESP	12.1	5.27	3.13	<1	<0.01	<0.01	9.5	<100	<0.2	<0.01	59
		01JH37core	DIW	8.2	5.50	1.93	<1	<0.01	<0.01	2.5	<100	0.2	<0.01	53
		01JH37core	ESP	12.5	5.19	1.08	<1	<0.01	<0.01	5.8	<100	<0.2	<0.01	43
		01JH37rind	DIW	10.7	5.50	2.33	<1	<0.01	<0.01	3.2	<100	<0.2	<0.01	52
		01JH37rind	ESP	12.1	5.41	1.21	<1	<0.01	<0.01	2.6	<100	<0.2	<0.01	42
<b>Ely</b> □		00JH34	DIW	26.2	4.79	1.97	<1	<0.01	<0.01	12	<100	0.3	<0.01	66
		00JH34	ESP	27.4	4.67	1.29	<1	<0.01	0.015	22	<100	<0.2	<0.01	58
		00JH38	DIW	28.2	4.86	0.29	<1	<0.01	0.026	31	<100	0.2	<0.01	43
		00JH38	ESP	32.7	4.28	n.d.	<1	<0.01	0.046	44	<100	0.3	<0.01	34
		01JH31A	DIW	259	3.86	n.d.	<1	<0.01	1.1	880	<100	0.5	<0.01	50
		01JH31A	ESP	294	3.69	n.d.	<1	<0.01	1.3	1,100	<100	0.2	<0.01	41
		01JH31B	DIW	504	3.62	n.d.	<1	<0.01	4.2	3,200	<100	0.4	<0.01	55
		01JH31B	ESP	557	3.55	n.d.	<1	<0.01	4.8	3,800	<100	0.2	<0.01	51
		01JH34	DIW	18.6	5.07	1.22	<1	<0.01	<0.01	9.7	<100	<0.2	<0.01	44
		01JH34	ESP	23.7	4.73	0.28	<1	<0.01	0.025	29	<100	<0.2	<0.01	32
<b>Ducktown</b> □		01CB23	DIW	895	4.17	n.d.	6.6	5.8	5.4	4,200	<100	0.4	<0.01	38
		01CB23	ESP	926	4.08	n.d.	5.3	6.4	5.4	4,200	<100	0.3	<0.01	28
		01CB25	DIW	35.3	5.50	3.14	<1	<0.01	<0.01	1.6	<100	0.2	<0.01	41
		01CB25	ESP	41.7	5.16	2.48	<1	<0.01	<0.01	2.4	<100	<0.2	<0.01	27
<b>Clayton</b> □		53JH00	DIW	20.4	5.65	3.19	<1	<0.01	<0.01	7.1	<100	52	<0.01	50
		53JH00	ESP	25.6	5.73	1.73	<1	<0.01	<0.01	9.2	<100	52	<0.01	40

<sup>a</sup> samples were leached with deionized water (DIW) and eastern synthetic precipitation (ESP).

<sup>b</sup> not determined

Table 7. (cont.)

sample		Ba	Ba	Be	Be	Bi	Ca	Ca	Cd	Cd	Ce	chloride	Co	Co	Cr	Cr
		ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-MS	IC	ICP-AES	ICP-MS	ICP-AES	ICP-MS
		µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
98JHNP-B-RS	DIW	1.5	1	<10	<0.05	<0.03	1.3	1	<5	1.5	2.7	0.1	11	9.5	<10	<1
98JHNP-B-RS	ESP	1.7	2	<10	<0.05	<0.03	1.5	1.2	<5	1.7	3.8	0.1	12	11	<10	<1
98JHNB-s	DIW	12	12	<10	0.06	<0.03	3.6	3	<5	0.75	1.3	0.1	19	17	<10	1
98JHNB-s	ESP	14	14	<10	<0.05	<0.03	4.1	3.6	<5	0.83	1.4	0.1	18	20	<10	1
00JH05	DIW	2.1	2	<10	<0.05	<0.03	0.64	0.52	<5	2.5	2.6	0.2	57	55	<10	<1
00JH05	ESP	2.7	2	<10	<0.05	<0.03	0.59	0.5	<5	2.6	3.1	0.1	54	55	<10	<1
01JH27	DIW	<1	0.8	<10	<0.05	<0.03	3.6	3	<5	0.2	4.5	0.2	21	20	<10	<1
01JH27	ESP	4.3	4	<10	0.08	<0.03	2.8	2.3	<5	0.2	5.1	0.2	19	18	<10	<1
01JH27Dup	DIW	<1	0.8	<10	<0.05	<0.03	2.8	2.4	<5	0.2	3.8	0.1	18	17	<10	<1
01JH27Dup	ESP	<1	1	<10	<0.05	<0.03	3.5	2.9	<5	0.2	5.8	0.2	21	22	<10	<1
01JH28	DIW	<1	0.8	<10	<0.05	<0.03	0.88	0.74	<5	0.9	0.38	0.1	29	28	<10	<1
01JH28	ESP	1.2	1	<10	<0.05	<0.03	0.84	0.69	<5	1	0.97	0.1	30	29	<10	<1
01JH28core	DIW	1.2	1	<10	<0.05	<0.03	0.45	0.4	<5	0.71	0.03	0.1	<10	4.8	<10	<1
01JH28core	ESP	1.8	2	<10	<0.05	<0.03	0.48	0.4	<5	0.71	<0.02	0.1	<10	4.8	<10	<1
01JH28rind	DIW	1	0.9	<10	<0.05	<0.03	0.48	0.4	<5	0.5	<0.02	0.1	<10	3.9	<10	<1
01JH28rind	ESP	1.5	2	<10	<0.05	<0.03	0.62	0.53	<5	0.81	0.11	0.1	<10	5.7	<10	<1
01JH37core	DIW	1.1	1	<10	<0.05	<0.03	0.21	0.2	<5	1.6	0.02	0.1	18	16	<10	<1
01JH37core	ESP	1.6	2	<10	<0.05	<0.03	0.24	0.2	<5	1.8	0.084	0.1	20	18	<10	<1
01JH37rind	DIW	<1	0.8	<10	<0.05	<0.03	0.32	0.3	<5	1	0.03	0.1	16	17	<10	<1
01JH37rind	ESP	1.7	2	<10	<0.05	<0.03	0.34	0.3	<5	1	0.04	0.1	16	17	<10	<1
00JH34	DIW	5.7	5.3	<10	<0.05	<0.03	1.3	1.1	<5	1.8	1.2	0.1	31	29	<10	<1
00JH34	ESP	7.1	6.9	<10	0.06	<0.03	1.3	1.1	<5	1.8	1.8	0.1	27	29	<10	<1
00JH38	DIW	2	2	<10	<0.05	<0.03	0.21	0.2	<5	1	1.6	0.1	46	46	<10	<1
00JH38	ESP	3.1	3	<10	<0.05	<0.03	0.21	0.2	<5	1.1	2	0.1	51	47	<10	<1
01JH31A	DIW	6.3	6.3	<10	0.08	<0.03	17	15	<5	3.2	69	0.2	320	340	<10	<1
01JH31A	ESP	6.4	6.4	<10	0.2	<0.03	19	17	<5	3.8	87	0.1	370	370	<10	<1
01JH31B	DIW	<1	0.1	<10	0.07	<0.03	16	14	10	7	34	0.3	640	630	12	12
01JH31B	ESP	<1	0.2	<10	0.05	<0.03	18	17	12	7.8	40	0.4	680	700	15	15
01JH34	DIW	3.7	4	<10	<0.05	<0.03	0.45	0.4	<5	0.86	1.4	0.2	38	35	<10	<1
01JH34	ESP	4.6	4	<10	<0.05	<0.03	0.43	0.3	<5	0.82	2.6	0.1	35	33	<10	<1
01CB23	DIW	<1	0.08	<10	0.2	<0.03	170	160	8	8.8	300	0.2	35	32	<10	<1
01CB23	ESP	<1	0.1	<10	0.2	<0.03	180	170	8.4	8.6	310	0.2	30	30	<10	<1
01CB25	DIW	3.6	4	<10	<0.05	<0.03	4.9	4.2	<5	0.07	0.02	0.2	<10	2	<10	<1
01CB25	ESP	4.4	4	<10	<0.05	<0.03	5.2	4.5	<5	0.1	0.06	0.2	<10	2.3	<10	<1
53JH00	DIW	5.1	5	<10	<0.05	<0.03	0.82	0.67	<5	0.3	1.4	0.2	<10	0.2	<10	<1
53JH00	ESP	6.5	5.8	<10	<0.05	<0.03	1	0.83	<5	0.4	2	0.1	<10	0.2	<10	<1

Table 7. (cont.)

		Cs	Cu	Cu	Dy	Er	Eu	Fe	Fe	Ga	Gd	Ge	Ho	In
		ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
sample														
98JHNP-B-RS	DIW	0.33	510	490	0.61	0.34	0.078	0.48	400	< 0.02	0.63	0.45	0.11	< 0.01
98JHNP-B-RS	ESP	0.42	700	680	0.81	0.4	0.098	0.71	540	< 0.02	0.63	0.42	0.17	< 0.01
98JHNB-s	DIW	0.2	230	240	0.57	0.4	0.049	2.8	2200	0.03	0.38	0.62	0.12	< 0.01
98JHNB-s	ESP	0.3	280	290	0.71	0.38	0.072	2.8	2400	< 0.02	0.5	0.65	0.14	< 0.01
00JH05	DIW	0.08	1,200	1,100	0.53	0.23	0.03	1.6	1300	< 0.02	0.42	0.3	0.088	< 0.01
00JH05	ESP	0.09	1,900	1,800	0.5	0.31	0.069	1.8	1500	< 0.02	0.46	0.3	0.11	< 0.01
01JH27	DIW	0.1	19	19	0.54	0.25	0.054	11	9100	< 0.02	0.47	0.5	0.12	< 0.01
01JH27	ESP	0.1	56	55	0.6	0.36	0.054	8.9	7100	< 0.02	0.65	0.54	0.13	< 0.01
01JH27Dup	DIW	0.09	18	19	0.34	0.25	0.04	10	8300	< 0.02	0.47	0.65	0.096	< 0.01
01JH27Dup	ESP	0.1	56	54	0.76	0.36	0.06	9.7	8000	< 0.02	0.78	0.65	0.15	< 0.01
01JH28	DIW	0.1	500	470	0.067	0.05	< 0.01	0.28	220	< 0.02	0.04	0.64	0.02	< 0.01
01JH28	ESP	0.2	920	870	0.14	0.095	< 0.01	0.5	400	< 0.02	0.16	0.3	0.02	< 0.01
01JH28core	DIW	0.02	210	200	0.01	< 0.02	< 0.01	0.077	59	< 0.02	< 0.03	0.5	< 0.005	< 0.01
01JH28core	ESP	0.02	220	210	0.01	< 0.02	< 0.01	0.062	51	< 0.02	< 0.03	0.67	< 0.005	< 0.01
01JH28rind	DIW	0.02	260	240	< 0.01	< 0.02	< 0.01	0.077	58	< 0.02	< 0.03	0.54	< 0.005	< 0.01
01JH28rind	ESP	0.03	530	520	0.02	< 0.02	< 0.01	0.2	170	< 0.02	< 0.03	0.3	0.007	< 0.01
01JH37core	DIW	0.03	620	580	< 0.01	< 0.02	< 0.01	0.099	79	< 0.02	< 0.03	0.74	< 0.005	< 0.01
01JH37core	ESP	0.04	950	920	0.02	< 0.02	< 0.01	0.18	150	< 0.02	< 0.03	0.4	0.005	< 0.01
01JH37rind	DIW	0.03	750	720	0.02	< 0.02	< 0.01	0.1	85	< 0.02	< 0.03	0.3	< 0.005	< 0.01
01JH37rind	ESP	0.04	890	860	0.02	< 0.02	< 0.01	0.13	110	< 0.02	< 0.03	0.4	< 0.005	< 0.01
00JH34	DIW	0.05	310	300	0.098	0.059	0.03	1.8	1400	< 0.02	0.08	0.4	0.02	< 0.01
00JH34	ESP	0.05	550	540	0.14	0.05	0.01	1.7	1400	< 0.02	0.16	0.3	0.03	< 0.01
00JH38	DIW	0.02	1,600	1,600	0.19	0.12	0.04	1.9	1500	< 0.02	0.22	0.4	0.04	< 0.01
00JH38	ESP	0.02	2,000	1,900	0.23	0.11	0.02	2.2	1800	< 0.02	0.22	0.42	0.04	< 0.01
01JH31A	DIW	0.06	3,100	3,100	6.7	3.6	2	18	15000	< 0.02	8	0.58	1.3	< 0.01
01JH31A	ESP	0.07	3,800	3,900	8.2	4	2.2	19	16000	< 0.02	9.7	0.82	1.5	< 0.01
01JH31B	DIW	0.2	20,000	18,000	29	13	5.7	55	45000	0.1	31	0.94	5	0.03
01JH31B	ESP	0.2	22,000	21,000	33	15	6.6	60	52000	0.1	36	0.91	5.6	0.03
01JH34	DIW	0.02	1,100	1,100	0.11	0.065	0.01	1.1	880	< 0.02	0.09	0.4	0.02	< 0.01
01JH34	ESP	0.03	1,800	1,700	0.18	0.13	0.03	1.3	1000	< 0.02	0.23	0.3	0.05	< 0.01
01CB23	DIW	0.34	1,100	1,000	15	6.7	10	0.41	190	< 0.02	21	0.41	2.5	< 0.01
01CB23	ESP	0.38	1,000	1,000	16	6.8	11	0.26	220	< 0.02	21	0.3	2.7	< 0.01
01CB25	DIW	0.02	110	99	< 0.01	< 0.02	< 0.01	0.037	19	< 0.02	< 0.03	0.58	< 0.005	< 0.01
01CB25	ESP	0.02	270	260	0.01	< 0.02	< 0.01	< 0.02	1.3	< 0.02	< 0.03	0.55	< 0.005	< 0.01
53JH00	DIW	0.03	690	650	0.084	< 0.02	0.041	< 0.02	12	< 0.02	0.06	0.8	0.01	< 0.01
53JH00	ESP	0.04	920	840	0.065	0.04	0.03	< 0.02	2.2	< 0.02	0.11	0.46	0.02	< 0.01

Table 7. (cont.)

		K	K	La	Li	Li	Mg	Mg	Mn	Mn	Mo	Mo	Na	Na
		ICP-AES	ICP-MS	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS
sample		mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
98JHNP-B-RS	DIW	0.83	680	1.3	<1	0.4	0.84	0.7	160	140	<20	0.086	1.1	1
98JHNP-B-RS	ESP	1	910	1.8	<1	<0.4	0.96	0.83	180	180	<20	1.2	1.3	1.2
98JHNB-s	DIW	0.18	160	0.58	<1	<0.4	1.5	1.3	380	370	<20	0.76	0.12	0.87
98JHNB-s	ESP	0.3	280	0.79	<1	<0.4	1.7	1.5	440	440	<20	0.48	0.16	0.16
00JH05	DIW	0.31	250	1.4	1.3	1.5	0.16	0.14	22	20	<20	0.11	0.81	0.7
00JH05	ESP	0.3	250	1.8	1.1	1.1	0.15	0.13	21	19	<20	0.12	0.7	0.61
01JH27	DIW	0.31	270	2.3	1.7	1	0.88	0.74	38	37	<20	2.3	0.59	0.58
01JH27	ESP	0.26	210	2.6	1.1	1	0.72	0.59	32	30	<20	7.5	0.5	0.41
01JH27Dup	DIW	0.27	230	1.9	1.2	0.9	0.78	0.68	34	32	<20	2.3	0.47	0.93
01JH27Dup	ESP	0.3	250	3	1.1	1	0.78	0.69	36	34	<20	0.84	0.56	0.53
01JH28	DIW	0.23	190	0.2	1.5	1.6	0.86	0.72	76	68	<20	0.25	0.39	0.33
01JH28	ESP	0.21	180	0.57	1.7	1.4	0.87	0.74	81	73	<20	0.16	0.34	0.41
01JH28core	DIW	0.16	140	0.02	<1	0.4	<0.1	0.05	12	9.7	<20	0.74	0.26	0.72
01JH28core	ESP	0.19	160	0.01	<1	0.5	<0.1	0.05	12	11	<20	0.69	0.29	0.26
01JH28rind	DIW	0.23	180	0.02	<1	0.7	<0.1	0.05	10	8.6	<20	0.84	0.39	0.32
01JH28rind	ESP	0.22	210	0.07	<1	0.7	<0.1	0.07	15	13	<20	0.33	0.41	0.36
01JH37core	DIW	0.18	150	0.02	1.7	0.8	<0.1	0.05	<10	4.2	<20	0.44	0.4	0.32
01JH37core	ESP	0.16	160	0.04	1.4	0.9	<0.1	0.06	<10	5.4	<20	0.22	0.42	1
01JH37rind	DIW	0.23	180	0.02	1.8	1.2	<0.1	0.08	<10	6.7	<20	0.33	0.57	0.5
01JH37rind	ESP	0.21	180	0.04	1.4	1.2	<0.1	0.08	<10	6.8	<20	0.28	0.56	0.48
00JH34	DIW	0.39	330	0.88	1.6	1.6	<0.1	0.07	44	39	<20	0.17	0.34	0.28
00JH34	ESP	0.41	350	1.2	1.2	1.5	<0.1	0.07	42	38	<20	0.13	0.34	0.6
00JH38	DIW	0.17	140	0.76	<1	<0.4	0.14	0.13	43	39	<20	0.14	0.17	0.14
00JH38	ESP	0.18	160	0.85	<1	<0.4	0.15	0.13	44	40	<20	0.1	0.18	0.15
01JH31A	DIW	<0.1	85	21	2.3	1.9	1.7	1.5	280	280	<20	0.43	0.35	0.35
01JH31A	ESP	0.12	120	27	2.7	2.3	2	1.7	320	310	<20	0.38	0.43	0.43
01JH31B	DIW	<0.1	16	9.2	2	1.7	4.9	4.3	100	100	<20	0.41	<0.1	0.07
01JH31B	ESP	<0.1	29	12	3	2	5.3	4.8	110	120	<20	0.36	<0.1	0.2
01JH34	DIW	0.26	220	0.71	<1	0.8	0.12	0.11	38	35	<20	0.21	0.25	0.21
01JH34	ESP	0.26	210	1.2	1	0.9	0.12	0.1	37	33	<20	0.14	0.23	0.2
01CB23	DIW	<0.1	21	110	4.8	4.1	12	10	400	400	<20	0.36	<0.1	0.13
01CB23	ESP	<0.1	23	120	4.7	4.5	11	9.5	380	390	<20	0.29	<0.1	0.06
01CB25	DIW	0.56	480	0.02	<1	<0.4	0.15	0.13	73	67	<20	0.14	<0.1	0.06
01CB25	ESP	0.58	500	0.05	<1	<0.4	0.15	0.12	83	75	<20	0.092	<0.1	0.06
53JH00	DIW	0.34	270	1	<1	<0.4	<0.1	0.04	130	120	<20	0.39	<0.1	0.41
53JH00	ESP	0.36	300	1.7	<1	<0.4	<0.1	0.04	160	140	<20	0.25	0.11	0.1

Table 7. (cont.)

		Nd	Ni	Ni	P	P	Pb	Pb	Pr	Rb	Re	Sb	Sb	Se
		ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-AES	ICP-MS	ICP-MS
sample		µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
98JHNP-B-RS	DIW	1.6	<10	1.8	<0.1	< 20	<50	0.4	0.34	4.9	0.09	<50	0.18	2
98JHNP-B-RS	ESP	2.3	<10	2.3	<0.1	< 20	<50	0.59	0.54	6	0.1	<50	0.11	3
98JHNB-s	DIW	1.1	<10	2.9	<0.1	< 20	<50	0.1	0.2	1.3	0.09	<50	0.08	0.7
98JHNB-s	ESP	1.1	<10	3.8	<0.1	< 20	<50	0.1	0.21	1.8	0.1	<50	0.05	0.7
00JH05	DIW	1.4	16	16	<0.1	< 20	<50	0.2	0.34	0.97	0.03	<50	0.75	< 0.2
00JH05	ESP	1.8	16	16	<0.1	< 20	<50	0.3	0.43	0.96	0.03	<50	0.37	< 0.2
01JH27	DIW	2	22	21	<0.1	< 20	<50	<0.05	0.55	1	0.02	<50	0.1	< 0.2
01JH27	ESP	2.4	34	30	<0.1	< 20	<50	<0.05	0.68	0.88	< 0.02	<50	0.15	< 0.2
01JH27Dup	DIW	1.8	24	23	<0.1	< 20	<50	<0.05	0.45	0.89	< 0.02	<50	0.15	< 0.2
01JH27Dup	ESP	3	38	34	<0.1	< 20	<50	<0.05	0.74	1.1	< 0.02	<50	0.1	< 0.2
01JH28	DIW	0.13	<10	8.8	<0.1	< 20	<50	0.62	0.05	0.68	0.02	<50	8.2	< 0.2
01JH28	ESP	0.56	12	10	<0.1	< 20	<50	0.2	0.1	0.76	< 0.02	<50	2.8	< 0.2
01JH28core	DIW	< 0.02	<10	2	<0.1	< 20	<50	<0.05	< 0.01	0.4	< 0.02	<50	0.04	< 0.2
01JH28core	ESP	0.03	<10	2	<0.1	< 20	<50	<0.05	< 0.01	0.4	< 0.02	<50	0.03	< 0.2
01JH28rind	DIW	0.04	<10	1.9	<0.1	< 20	<50	<0.05	< 0.01	0.52	< 0.02	<50	<0.03	< 0.2
01JH28rind	ESP	0.04	<10	3.1	<0.1	< 20	<50	<0.05	< 0.01	0.66	< 0.02	<50	<0.03	< 0.2
01JH37core	DIW	0.03	13	15	<0.1	< 20	<50	<0.05	< 0.01	0.5	< 0.02	<50	<0.03	< 0.2
01JH37core	ESP	0.062	18	16	<0.1	< 20	<50	<0.05	< 0.01	0.52	< 0.02	<50	<0.03	< 0.2
01JH37rind	DIW	0.04	15	16	<0.1	< 20	<50	<0.05	< 0.01	0.55	< 0.02	<50	<0.03	< 0.2
01JH37rind	ESP	0.03	19	17	<0.1	< 20	<50	<0.05	< 0.01	0.57	< 0.02	<50	<0.03	< 0.2
00JH34	DIW	0.48	<10	8	<0.1	< 20	<50	1	0.1	1.1	< 0.02	<50	9.4	< 0.2
00JH34	ESP	0.75	<10	8.2	<0.1	< 20	<50	0.5	0.2	1.1	< 0.02	<50	1.6	< 0.2
00JH38	DIW	0.7	12	13	<0.1	< 20	<50	11	0.2	0.4	0.03	<50	1.4	< 0.2
00JH38	ESP	0.83	13	12	<0.1	< 20	<50	18	0.21	0.5	0.02	<50	1	< 0.2
01JH31A	DIW	47	77	71	<0.1	< 20	<50	<0.05	10	0.58	0.23	<50	0.06	2
01JH31A	ESP	56	90	81	<0.1	< 20	<50	0.05	12	0.78	0.27	<50	0.04	3
01JH31B	DIW	73	190	170	0.19	< 20	<50	<0.05	11	0.2	0.2	<50	0.06	1
01JH31B	ESP	86	210	190	0.34	< 20	<50	<0.05	13	0.3	0.2	<50	0.04	1
01JH34	DIW	0.6	<10	9.9	<0.1	< 20	<50	<0.05	0.1	0.58	< 0.02	<50	<0.03	< 0.2
01JH34	ESP	0.88	10	9.3	<0.1	< 20	<50	0.2	0.24	0.6	< 0.02	<50	2.3	< 0.2
01CB23	DIW	170	<10	0.6	<0.1	30	<50	0.1	43	0.68	0.05	<50	0.06	0.9
01CB23	ESP	170	<10	0.6	<0.1	< 20	<50	0.2	44	0.99	0.07	<50	0.05	0.9
01CB25	DIW	< 0.02	<10	0.2	<0.1	< 20	<50	0.08	< 0.01	1	< 0.02	<50	0.45	< 0.2
01CB25	ESP	< 0.02	<10	0.3	<0.1	< 20	<50	<0.05	0.04	1.1	< 0.02	<50	0.24	< 0.2
53JH00	DIW	0.52	<10	3	<0.1	< 20	8,200	8,400	0.1	0.61	< 0.02	200	230	< 0.2
53JH00	ESP	0.74	<10	3.8	<0.1	< 20	11,000	11,000	0.2	0.69	< 0.02	250	290	< 0.2

Table 7. (cont.)

		Si	SiO <sub>2</sub>	Sm	sulfate	SO <sub>4</sub>	Sr	Sr	Tb	Th	Tl	Tm	Ti	U
		ICP-AES	ICP-MS	ICP-MS	IC	ICP-MS	ICP-AES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-AES	ICP-MS
sample		mg/L	mg/L	µg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
98JHNP-B-RS	DIW	5.6	11	0.4	17	15	2.9	2.6	0.098	< 0.08	0.1	0.044	<50	0.06
98JHNP-B-RS	ESP	4	7.7	0.6	21	19	3.5	3.4	0.11	< 0.08	0.1	0.055	<50	0.08
98JHNB-s	DIW	19	37	0.28	35	34	2.3	2.1	0.068	< 0.08	<0.05	0.047	<50	0.09
98JHNB-s	ESP	3.5	7	0.31	40	43	2.9	2.5	0.088	< 0.08	<0.05	0.052	<50	0.1
00JH05	DIW	4.6	8.8	0.36	10	8	3.2	3.1	0.063	< 0.08	<0.05	0.026	<50	0.09
00JH05	ESP	4.1	7.8	0.4	11	9.8	3.2	2.9	0.093	< 0.08	<0.05	0.029	<50	0.1
01JH27	DIW	19	37	0.49	35	34	4.4	4	0.081	< 0.08	<0.05	0.032	<50	0.05
01JH27	ESP	15	29	0.65	27	27	3.8	3.4	0.11	< 0.08	<0.05	0.047	<50	0.06
01JH27Dup	DIW	6.2	12	0.44	30	29	3.5	3.4	0.08	< 0.08	<0.05	0.037	<50	0.04
01JH27Dup	ESP	15	29	0.59	32	32	4	4.1	0.099	< 0.08	<0.05	0.063	<50	0.06
01JH28	DIW	23	44	< 0.02	4.8	5	1.1	1	0.007	< 0.08	<0.05	< 0.006	<50	0.01
01JH28	ESP	3.7	7	0.22	8.2	5.9	1.2	1	0.03	< 0.08	<0.05	0.01	<50	0.02
01JH28core	DIW	22	44	< 0.02	0.7	< 0.3	1.5	1.3	< 0.005	< 0.08	<0.05	< 0.006	<50	< 0.005
01JH28core	ESP	15	30	< 0.02	1.5	< 0.3	1.6	1.4	< 0.005	< 0.08	<0.05	< 0.006	<50	< 0.005
01JH28rind	DIW	24	45	< 0.02	0.4	< 0.3	1.5	1.4	< 0.005	< 0.08	<0.05	< 0.006	<50	0.005
01JH28rind	ESP	4.1	8	< 0.02	2	< 0.3	1.9	2	< 0.005	< 0.08	<0.05	< 0.006	<50	0.007
01JH37core	DIW	23	45	< 0.02	1.4	< 0.3	1	0.9	< 0.005	< 0.08	<0.05	< 0.006	<50	0.01
01JH37core	ESP	5.6	11	< 0.02	2.9	1.2	1.2	1.1	< 0.005	< 0.08	<0.05	< 0.006	<50	0.01
01JH37rind	DIW	6.9	14	< 0.02	1.9	< 0.3	1.2	1.1	< 0.005	< 0.08	<0.05	< 0.006	<50	0.007
01JH37rind	ESP	5.6	11	0.03	3.1	1.3	1.3	1.2	< 0.005	< 0.08	<0.05	< 0.006	<50	0.008
00JH34	DIW	19	37	0.098	8.6	6.5	7.7	7	0.02	< 0.08	<0.05	< 0.006	<50	0.04
00JH34	ESP	6	12	0.15	9.3	6.9	8	7.3	0.02	< 0.08	<0.05	0.01	<50	0.05
00JH38	DIW	5.5	11	0.16	8.8	6.4	<1	0.9	0.03	< 0.08	<0.05	0.02	<50	0.03
00JH38	ESP	5.5	11	0.26	10	8.2	1	0.9	0.03	< 0.08	<0.05	0.02	<50	0.03
01JH31A	DIW	4.6	9.4	10	100	110	5	4.9	1.2	< 0.08	<0.05	0.52	<50	0.63
01JH31A	ESP	4	8	12	110	130	6.2	6	1.4	< 0.08	<0.05	0.62	<50	0.72
01JH31B	DIW	4.4	9.1	29	170	250	<1	0.8	5.1	0.1	<0.05	1.7	<50	1.3
01JH31B	ESP	5.4	12	34	250	290	1	1	5.7	0.1	<0.05	2	<50	1.4
01JH34	DIW	7.5	15	0.05	5.5	4.2	2	1.9	0.03	< 0.08	<0.05	0.01	<50	0.01
01JH34	ESP	4	7.6	0.21	7.5	5	2.1	1.8	0.03	< 0.08	<0.05	0.01	<50	0.02
01CB23	DIW	5.9	12	31	490	600	270	270	2.8	0.43	0.2	0.85	<50	4.8
01CB23	ESP	5.5	11	32	520	610	280	280	2.9	0.53	0.2	0.96	<50	5
01CB25	DIW	19	37	< 0.02	11	9.5	24	23	< 0.005	< 0.08	<0.05	< 0.006	<50	< 0.005
01CB25	ESP	3.9	7.4	< 0.02	13	12	27	25	< 0.005	< 0.08	<0.05	< 0.006	<50	0.005
53JH00	DIW	20	40	0.05	4.7	2.7	19	17	0.008	< 0.08	<0.05	< 0.006	<50	0.008
53JH00	ESP	5.5	11	0.12	7.5	5.1	27	23	0.02	< 0.08	<0.05	< 0.006	<50	< 0.005

Table 7. (cont.)

		V	V	W	Y	Yb	Zn	Zn
		ICP-AES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-AES	ICP-MS
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
sample								
98JHNP-B-RS	DIW	<10	<0.2	< 0.3	3.4	0.4	80	73
98JHNP-B-RS	ESP	<10	<0.2	< 0.3	4.4	0.33	91	88
98JHNB-s	DIW	<10	<0.2	< 0.3	3.3	0.27	58	57
98JHNB-s	ESP	<10	<0.2	< 0.3	3.8	0.45	69	67
00JH05	DIW	<10	<0.2	< 0.3	2.7	0.15	450	420
00JH05	ESP	<10	<0.2	< 0.3	3.2	0.21	450	420
01JH27	DIW	<10	<0.2	< 0.3	3.4	0.22	73	70
01JH27	ESP	<10	<0.2	< 0.3	4	0.29	81	76
01JH27Dup	DIW	<10	<0.2	< 0.3	2.9	0.16	69	64
01JH27Dup	ESP	<10	<0.2	< 0.3	4.3	0.35	86	78
01JH28	DIW	<10	<0.2	< 0.3	0.48	< 0.02	290	270
01JH28	ESP	<10	<0.2	< 0.3	1.3	0.08	330	300
01JH28core	DIW	<10	<0.2	0.6	0.042	< 0.02	79	76
01JH28core	ESP	<10	<0.2	0.4	0.02	< 0.02	85	79
01JH28rind	DIW	<10	<0.2	0.4	0.03	< 0.02	83	74
01JH28rind	ESP	<10	<0.2	< 0.3	0.11	0.03	120	110
01JH37core	DIW	<10	<0.2	0.4	0.04	< 0.02	180	170
01JH37core	ESP	<10	<0.2	< 0.3	0.17	< 0.02	210	200
01JH37rind	DIW	<10	<0.2	< 0.3	0.089	< 0.02	190	180
01JH37rind	ESP	<10	<0.2	< 0.3	0.1	< 0.02	200	180
00JH34	DIW	<10	<0.2	< 0.3	0.67	0.04	340	320
00JH34	ESP	<10	<0.2	< 0.3	0.94	0.04	350	330
00JH38	DIW	<10	<0.2	< 0.3	1	0.11	190	180
00JH38	ESP	<10	<0.2	< 0.3	1.2	0.11	210	180
01JH31A	DIW	<10	<0.2	< 0.3	31	3.4	460	440
01JH31A	ESP	<10	<0.2	< 0.3	38	3.8	530	510
01JH31B	DIW	45	40	< 0.3	99	10	360	350
01JH31B	ESP	35	32	< 0.3	120	12	430	420
01JH34	DIW	<10	<0.2	< 0.3	0.66	0.065	160	150
01JH34	ESP	<10	<0.2	< 0.3	1	0.1	160	150
01CB23	DIW	<10	<0.2	< 0.3	68	5.8	4,200	3,900
01CB23	ESP	<10	<0.2	< 0.3	69	5.6	4,100	3,600
01CB25	DIW	<10	<0.2	< 0.3	0.02	< 0.02	320	290
01CB25	ESP	<10	<0.2	< 0.3	0.03	< 0.02	500	470
53JH00	DIW	<10	<0.2	0.9	0.38	0.03	340	310
53JH00	ESP	<10	<0.2	0.4	0.58	0.052	400	370



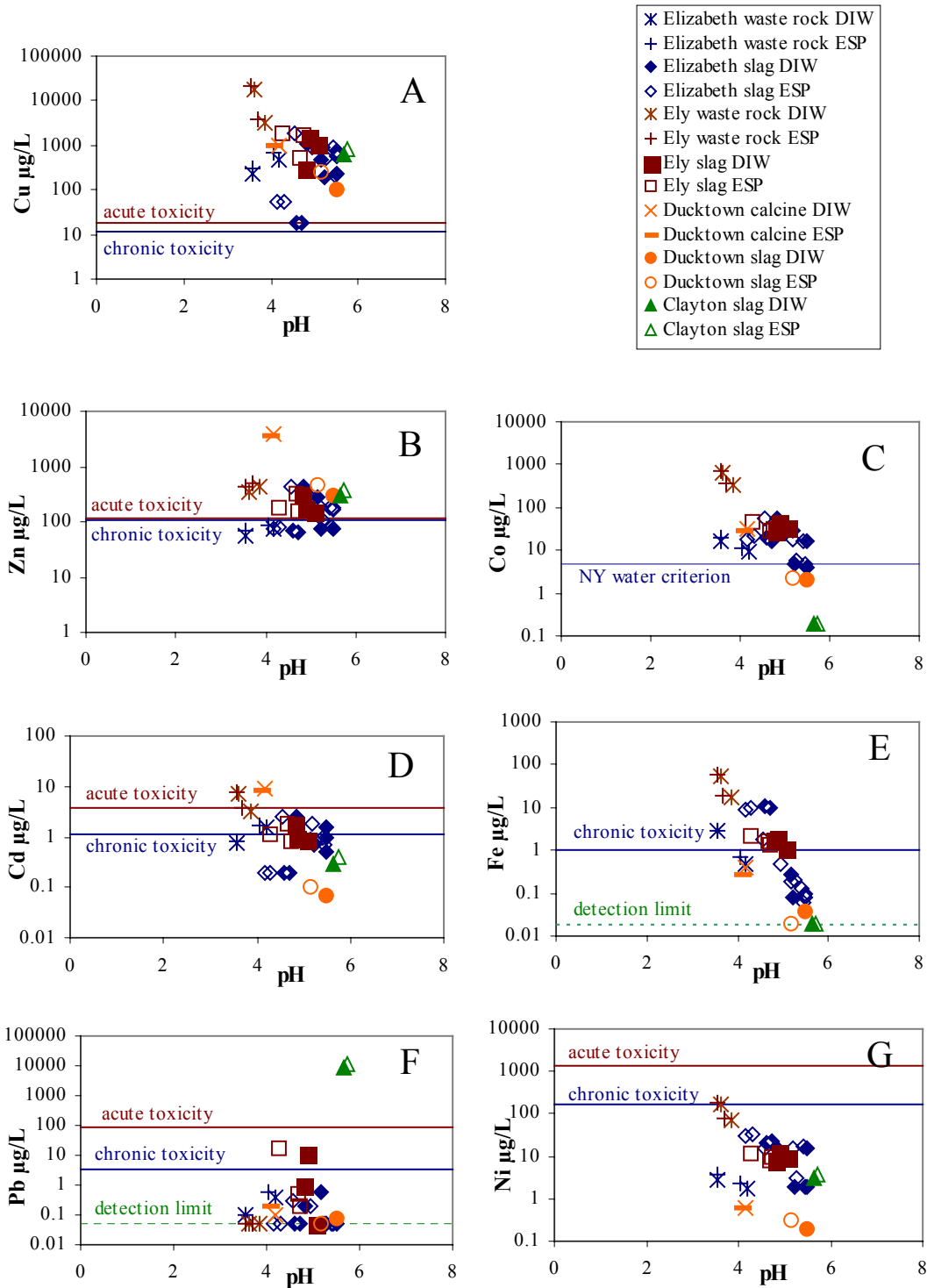


Figure 16. Concentration of A. Cu, B. Zn, C. Co, D. Cd, E. Fe, F. Pb, and G. Ni in leachates. Leaching tests were performed using deionized water (DIW) and eastern synthetic precipitation (ESP). Water-quality guidelines for the protection of aquatic life (U.S. E.P.A., 1993) based on an assumed hardness of 100 mg/L  $\text{CaCO}_3$  are labeled for all elements except Co, for which the N.Y. water criterion is labeled.

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