A SUPPLEMENTAL SPECIATION REPORT ON SOILS FROM THE OMAHA COMMUNITY--- OMAHA, NEBRASKA.

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FOR

Black & Veatch

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Region VII

BY

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1.0 INTRODUCTION

In August, 2000, Black and Veatch, on behalf of U.S. Environmental Protection Agency (USEPA) requested the Laboratory for Environmental and Geological Studies (LEGS), at the University of Colorado, to undertake an apportionment /characterization study on residential soils from the Omaha Lead Site (OLS). In response to this request a mineralogical and geochemical study was conducted on community and potential source soils in order to characterize the form(s) of lead, their isotopic character, and bioavailability . Samples were acquired from the former ASARCO lead refinery, Gould secondary lead smelter, and from community soils by representatives of the USEPA. A report (Drexler, 2002), was issued based on these studies. In 2006 LEGS was tasked to expand the areal distribution of lead speciation characteristics for community soils (2007 data set). The sample set includes residential yards, gardens, community parks, and vacant lots. Table 1. A site map with sample locations for both studies is provided in Figure 1. This report will summarize lead speciation characteristics of the 2007 data set, and combined 2002-2007 data sets. It will also provide updated conclusions on lead apportionment at the OLS using all available data.

Initial review of historical documents (Marcosson, 1949; ASARCO, 2005; Gould, 2005; Iles,1902; Hoffman, 1918; USEPA, 1993; Eilers, 1912; Mullins, 1979; and USEPA, 2004b) identified three primary pyrometallurgical (smelters) facilities, the ASARCO Grant/Omaha lead refinery, the Gould secondary smelter and battery recycler, and the Carter white lead pigment manufacturing facility operating on the eastern edges of central Omaha, Nebraska, along the banks of the Missouri River.

The Gould Secondary Smelter operated from the early 1950's thru 1982, with a lead production rate of approximately 20,000 tons/year. It was originally built to reclaim lead from storage batteries and other scrap sources, producing both native lead and antimony-lead ingots. The facility consisted of two reverberatory furnaces and seven refining kettles, while smelting was carried out in a blast furnace constructed at the facility. Baghouses (devices used to minimize stack emissions) were introduced to the facility in the early 1970's to limit the loss of metal from fumes, however the facility continued to exhibit uncontrolled emissions until its closure in 1982. Facility soils were highly contaminated, with test borings ranging from 3800-152,000 mg/kg Pb at 0-30" and up to 1700 mg/kg at 10' (Neyer et al.,1988).

The ASARCO smelter, initially referred to as the Grant and then later as the Omaha smelter, operated from 1871 thru 1997 (5 times longer than Gould) with an estimated lead production rate of more than 100,000 tons/year for much of its 126 year history. It was built as a lead refinery, processing "pig" lead ingots, recovering Au, Ag,Cu, Zn, Te, Sb, and Bi. The facility consisted of two reverberatory and one blast furnace for its copper circuit, eighteen refining kettles with six softening furnaces for its lead circuit, along with smaller, antimony and bismuth facilities. Baghouses, six in total, were introduced to the facility in the early 1900's to limit the loss of metal from fumes. ASARCO plant soils were highly contaminated, with soils ranging from 528-197,206 mg/kg Pb at 0-5' (Drexler, 2002).

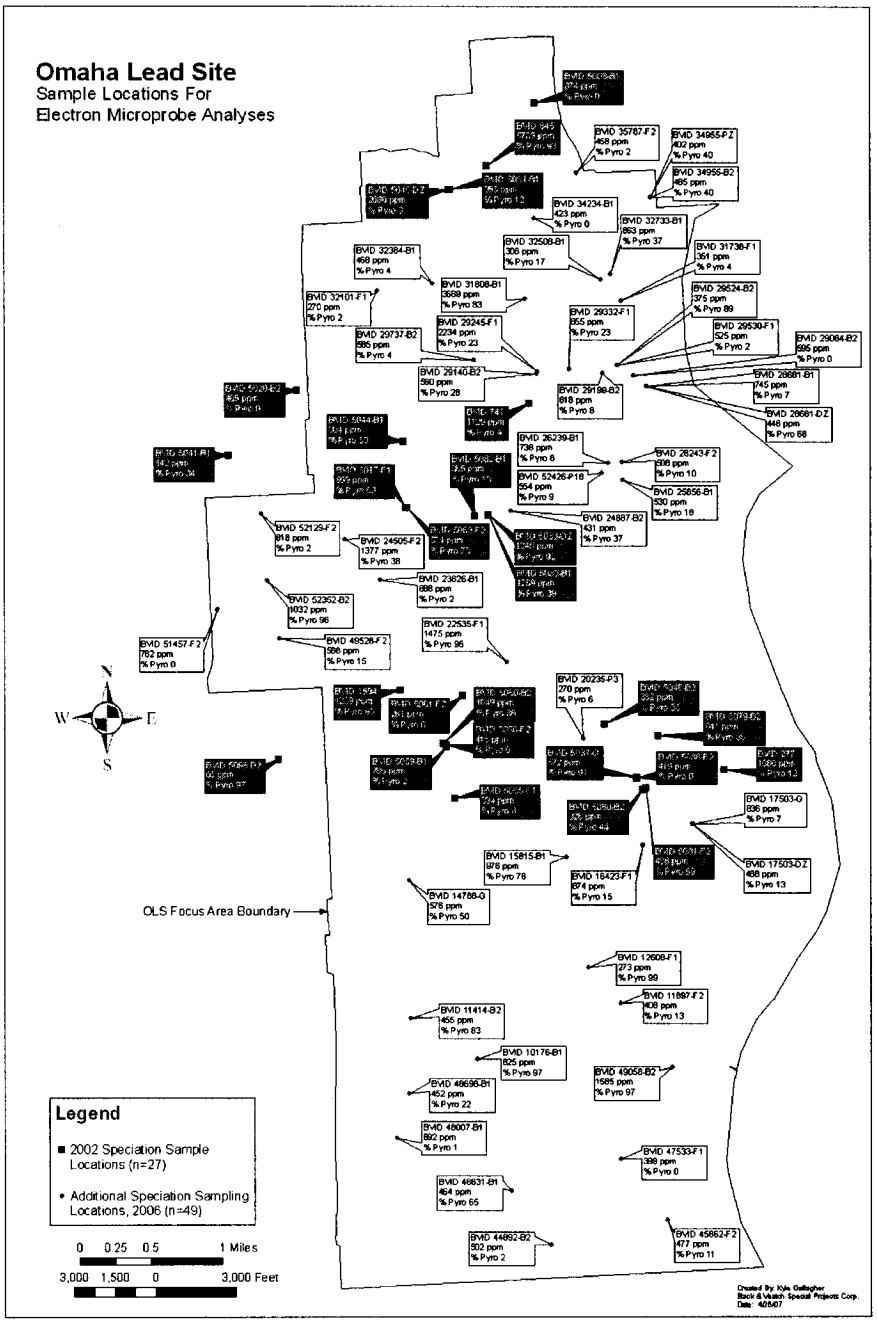
The Carter white lead pigment plant was founded in 1885 from the Omaha White Lead Co. After a fire at the facility in 1890, Carter rebuilt the plant with a capacity of 10,000 tons/year and

operated at nearly capacity until 1899, when the plant closed. In 1903, with the death of Carter, new owners reopened the plant and operated until 1906, when National Lead acquired the facility and closed it for a final time to consolidate the industry. Thus Carter's operational longevity is comparable to that of Gould (20 years); however, its capacity was half as great as Gould and its capacity was more than an order of magnitude smaller than ASARCO.

Table 1. Supplemental 2007 Speciation Samples

BVID	PROPERTY TYPE	Year built	Type of Home	DRIP	Front Left YA	Front Right YB	Back Left YC	Back Right YD	Garden GZ
				0-2" Bulk Lead Concentrations mg/kg					
52426	Park								
20235	Park								
48007	Residence	1910	frame vinyl				891.6		
10176	Residence	1905	frame stucco				825.5		
49058	Vacant Lot							1584.8	
15815	Residence	1900	frame vinyl				976.2		
16423	Residence	1890	frame aluminum		873.7				
17503	Residence	1886	siding	487.7			836.2		274.2
29737	Vacant Lot							585.0	
31808	Vacant Lot						3669.0		
31738	Vacant Lot				351.0				
32733	Vacant Lot						863.5		
52352	Residence	1952	masonry veneer					1031.7	
51457	Residence	1915	brick			782.4			
52129	Residence	1916	siding			818.2			
22535	Residence	1916	Brick		1475.5				
24605	Residence	1910	frame aluminum			1377.3			
23626	Residence	1910	siding				888.0		
34955	Vacant Lot							485.0	
24887	Vacant Lot							431.4	
32384	Vacant Lot						468.0		
29140	Vacant Lot							560.3	
25656	Vacant Lot						530.4		
26243	Vacant Lot					507.7			
26239	Vacant Lot						738.3		
28681	Residence	1905	siding	445.7			745.3		
29084	Vacant Lot							595.1	
29530	Vacant Lot				524.5				
29199	Vacant Lot							618.2	
29332	Vacant Lot				654.6				
34234	Vacant Lot						423.4		
29245	Vacant Lot				2233.5				
29524	Vacant Lot							**375.2**	
32508	Residence	1895	siding				**306.4**		
32101	Residence	1900	frame vinyl		**270.1**				
35787	Vacant Lot					458.0			
46631	Residence	1890	siding				464.2		
48698	Residence	1910	frame stucco				451.6		
12608	Residence	1910	siding		272.6				
11897	Residence	1913	siding			408.0			
11414	Residence	1912	frame aluminum					305.1	
14788	Vacant Lot								576.0
49528	Residence	1913	siding			588.4			
45862	Residence	1955	frame vinyl			476.5			
44992	Residence	1908	siding					502.2	
47533	Residence	1900	frame vinyl		398.6				

Figure1


Omaha Lead Site
Sample Locations For
Electron Microprobe Analyses
OLS Focus Area Boundary
Legend
2002 Speciation Sample Locations (n=27)
Additional Speciation Sampling Locations, 2006 (n=49)
0 0.25 0.5 1 Miles
3,000 1,500 0 3,000 Feet
N
W
E
S

2.0 LEAD SPECIATION METHODOLOGY

Expanding on the 2002 sampling, the 2007 data set consists of an additional forty-nine soil samples from the OLS (Figure 1) which were speciated for lead using electron microprobe (EMPA) techniques. Methodologies used for sample preparation, data collection, and data synthesis are described below.

2.01 Method

Metal speciation was conducted on a JEOL 8600 electron microprobe (EMPA), operating at 15Kv (accelerating voltage) and 15-20 NanoAmp current, at the Laboratory for Geological Studies at the University of Colorado following the laboratory's SOP. One exception was made in the SOP, in that the samples were not sieved to <250 μm, as is most common for bioavailability determinations, but the 2mm fraction was used in order to be consistent with previous site studies in which lead sourcing and/or apportionment are the primary task (USEPA 2002, 2003, 2004 and CDPHE, 1998). The samples were all air dried and prepared for speciation analysis as outlined in the Standard Operating Procedure (SOP– Appended to Drexler, 2002). A combination of both an Energy Dispersive Spectrometer (EDS) and a Wavelength Dispersive Spectrometer (WDS) were used to collect x-ray spectra and determine elemental concentrations on observed mineral phases. All quantitative analyses are based on certified mineral and metal standards using a Phi Rho Z correction procedure. Representative backscatter photomicrographs

(BSPM) illustrating sample characteristics were acquired.

Data from EMPA will be summarized using three methods. The first method is the determination of FREQUENCY OF OCCURRENCE (F). This is calculated by summing the longest dimension of all the lead-bearing phases observed and then dividing each phase by the total length for all phases.

Equation 1.0 will serve as an example of how to calculate the frequency of occurrence for a

Lead- bearing compound.

F_{Pb} - Frequency of occurrence of lead in a single phase.

PLD - An individual particle's longest dimension

$$F_{Pb} \text{ in phase-1} = \frac{\sum (PLD)_{phase\text{-}1}}{\sum (PLD)_{phase\text{-}1} + \sum (PLD)_{phase\text{-}2} + \sum (PLD)_{phase\text{-}n}} \qquad \text{Eq. 1.0}$$

$$\%F_{Pb} \text{ in phase-1} = F_{Pb} \text{ in phase-1} * 100$$

Thus, the frequency of occurrence of lead in each phase (F_{Pb}) is calculated by summing the longest dimension of all particles observed for that phase and then dividing each phase by the

total of the longest dimensions for all phases. The data generated thus illustrate which lead-bearing phase(s) are the most commonly observed in the sample or relative volume percent.

The second calculation used in this report determines the RELATIVE MASS lead (RM_{Pb}) in a phase. These data are calculated by substituting the PLD term in the equation above with the value of RM_{Pb}. This term is calculated using the formula below.

RM_{Pb} - Relative mass of lead in a phase

SG - Specific gravity of a phase

ppm_{Pb} - Concentration in ppm of lead in phase (see Table 2.0A, Drexler,2002)

$$RM_{Pb} = F_{Pb} * SG * ppm_{Pb} \qquad \text{Eq. 2.0}$$

The advantage in reviewing the RELATIVE MASS lead determinations is that it gives one information as to which metal-bearing phase(s) in a sample is likely to control the total bulk concentration for lead. As an example, PHASE-1 may, by relative volume, contribute 98% of the sample, however it has a low specific gravity and contains only 1000 ppm lead, whereas PHASE-2 contribute 2% of the sample, has a high specific gravity and contains 850000 ppm of lead. In this example it is PHASE-2 that is the dominant source of lead to the sample.

The third calculation is to determine the MINERAL MASS lead (Min_{Pb}). In this calculation the RM_{Pb} is simply multiplied by the bulk concentration of lead found in the sample:

$$Min_{Pb} = RM_{Pb} * Pb_{Bulk} \qquad \text{Eq. 3.0}$$

Where Pb_{Bulk} is the bulk lead for the sample speciated. These values are most useful for geostatistical calculations, such as kriging, or apportionment since values are not forced to 100%.

2.02 Point Counting

In order to perform the above calculations a population (counts) of lead-bearing particles must be determined for an individual sample. Counts of lead-bearing particles are made by traversing each sample from left-to-right and top-to-bottom on the EMPA. The amount of vertical movement for each traverse would depend on magnification and CRT (cathode-ray tube) size. This movement should be minimized so that NO portion of the sample is missed when the end of a traverse is reached. Two magnification settings should be used. One ranging from 40 to 100X and a second from 300 to 600X. The last setting will allow one to find the smallest identifiable (0.5-1 micron) phases.

The portion of the sample examined in the second pass, under the higher magnification, will depend on the time available, the number of lead-bearing particles, and the complexity of metal mineralogy. A maximum of 8 hours or 100 total particles will be spent per sample. This criteria is chosen to optimize the acquisition of a statistically meaningful particle count in a single sample with the overall characterization of a site.

2.03 Precision and Accuracy

The precision of the EMPA speciation will be determined based on sample duplicates run every 20 samples. The accuracy of an analysis will be estimated from a statistical evaluation of point counting data based on the method of Mosimann (1965).

3.0 POTENTIAL LEAD SOURCES TO THE OMAHA COMMUNITY.

Based on an evaluation of the Omaha community and its historical growth it is believed that there are two primary sources to the elevated lead concentrations found in the community soils (Dynamac[1,2]; Steen[3]; and Medine et al., 2007). These sources include: an anthropogenic input (paint and gasoline) and pyrometallurgical input(s).

A number of facilities in the area can be characterized as pyrometallurgical facilities and during their operational histories numerous sources (reverberatory and blast furnaces, kettles, storage piles, and baghouses) may have contaminated the OLS with heavy metals, primarily as emissions.

Based on information presented in the Dynamac Reports and the Steen Report, ASARCO, Gould

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[1]Dynamac Corporation, 2000. Omaha Lead Tables, prepared for U. S. EPA Region 7 under Contract No. 68-W4-0039, C07007-PYK, March 9 Dynamac Corporation, 1999. Summary of company Articles from Library Archives, Contract No. 68-W4-0039, C07007, Omaha Lead site, Omaha, Nebraska, September 1.

[2] Dynamac Corporation, 1999. Summary of company Articles from Library Archives, Contract No. 68-W4-0039, C07007, Omaha Lead site, Omaha, Nebraska, September 1.

[3] Rodger G. Steen, Air Sciences, Inc., 2005. Preliminary Estimates of Historic Lead Emissions in Omaha, prepared for the Union Pacific Railroad Company, Project No. 207-1, December 15.

and Carter White Lead are the three major potential lead contributors to the area, with estimated lead emissions of:[4]

ASARCO Lead Refinnery	**168830 tons**
Gould Battery Recycling	**1203 tons**
Carter White Lead	**1092 tons**

The remaining identified operations are potential minor contributors to the OLS problem with each estimated at less than 20 tons of lead emissions during its operational period and included the following:

Paxton-Mitchell Co.	Davis and Cowgill Foundry
Omaha Shot & Lead Works	Omaha Steel Works
Lawrence Shot and Lead Co.	Donway-Thorpe Co.
Electric Storage Battery Co.	Western Smelting and Refining Co.
Phenix Foundry and Machine Co.	Paxton and Vierling Iron Works
Reifschneider Paint Co.	Grant Storage Battery
Omaha White Lead Works	Industrial Battery Co.

Only the ASARCO and Gould plant sites were available for sampling. In terms of the historical speciation of lead at both sites, these samples are most certainly incomplete, as the soils have been disturbed during their operation by construction/demolition and flooding. Thus these samples may provide only a partial "source fingerprint".

Although all three of the primary facilities (ASARCO, Gould, and Carter) are likely to produce

4 Medine, A., Drexler, J.W., and Thyne, G. 2007. Analysis of Lead Sources in the Omaha Lead Site Area - Total Lead Emissions from the ASARCO Smelter in Comparison to Other Industrial Sources, Lead Paint and Leaded Gasoline. Black and Veatch.

quantities of lead oxide (PbO), and lead carbonate ($PbCO_3$), some variations in lead speciation between the three facilities can be predicted based on process knowledge.

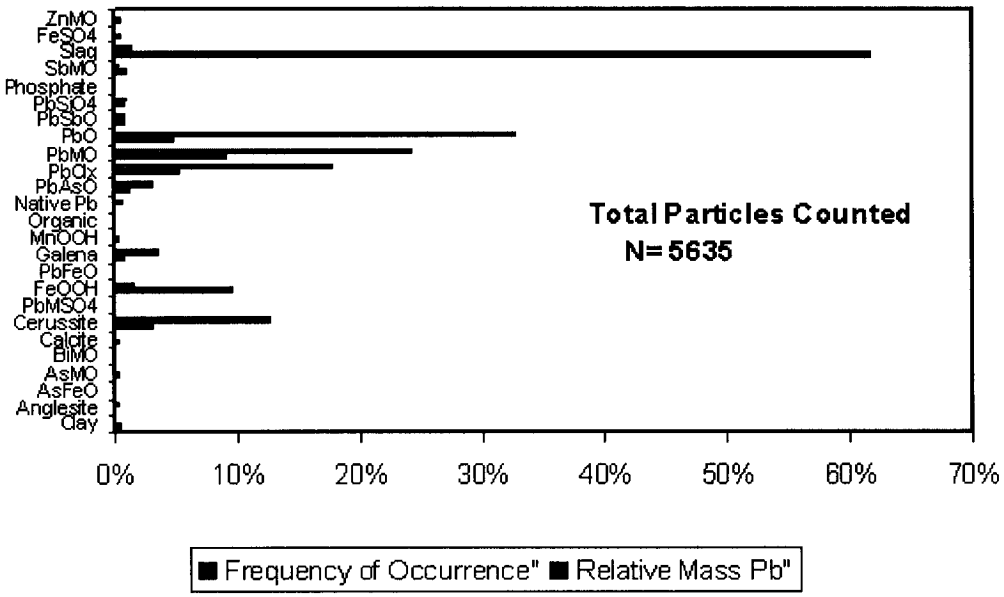
The ASARCO facility's copper converter will produce PbAsO, slag, PbSbO and leaded oxides/sulfates of Cu, Sb and As, while ASARCO's lead refinery will produce by products of $PbCl_2$, $PbSiO_4$, and leaded oxides/sulfates of Bi and Zn. The Gould facility, on the other hand, should have a greater association with metallic Pb, and $PbSO_4$, based on known lead-battery recycling operations, along with possible oxides/sulfates of Cr and Sb. The Carter facility would have utilized the Carter process for production of basic lead carbonate, and thus would have potentially emitted metallic Pb, PbO, and $PbCO_3$.

3.01 ASARCO-Plant-site Summary

Soil samples from the ASARCO facility were collected between 0-4.5 feet in depth and ranged in bulk lead concentration from 500-197200 mg/kg. Plant samples studied have lead masses dominated (94% of the relative lead mass) by the following lead-bearing phases: PbO, PbMO, $PbCl_2$ and $PbCO_3$. The soils within the ASARCO facility are not homogeneous in lead speciation. Approximately 62% of the samples had a single lead phase controlling the samples relative lead mass. Nearly 87% of the samples were dominated by only one or two lead phases. In fact, PbS and $PbSO_4$ dominated the relative lead mass in some samples even though their facility-wide

abundance was minor. It is likely this is a result of the multiple extraction circuits found at the facility, i.e., $PbCl_2$ from the dezincing circuit, PbO from the lead kitchens, and PbMO from the antimony and copper circuits.

Figure 2. EPA Omaha ASARCO "Plant Samples.

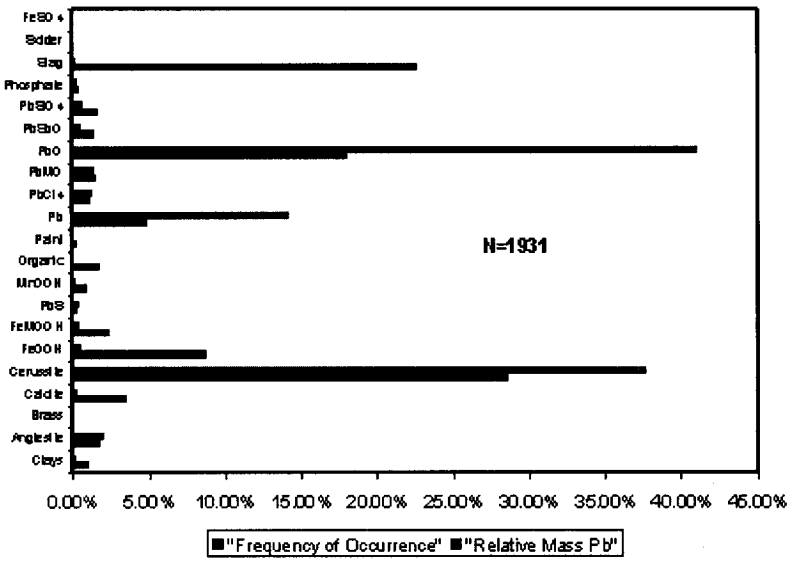


3.02 GOULD Park-site Samples Summary

Gould (also referred to as Park or Park-site) samples studied were collected from borings ranging in depth between 0-12 feet, with bulk lead concentrations between 450-6200 mg/kg. Sample lead masses were dominated (93% of the relative lead mass) by the following lead-bearing phases: PbO, $PbCO_3$, and native Pb (metallic lead). Figure 3.

The dominant occurrence of $PbCO_3$ at a battery recycling facility is perhaps in question, but it is likely the result of the oxidation of native lead to $PbCO_3$ in high pH-Eh environments. As has been documented (Garrels and Christ (1965) and Kabata and Pendias (1984 and 1993)) under normal near-surface conditions, $PbCO_3$/PbO, and $PbSO_4$ are the stable lead forms and the stability of native lead would require reduced alkaline conditions. The author has found this to be a common transition in the many shooting ranges studied across the country (USDOD 2001-2002).

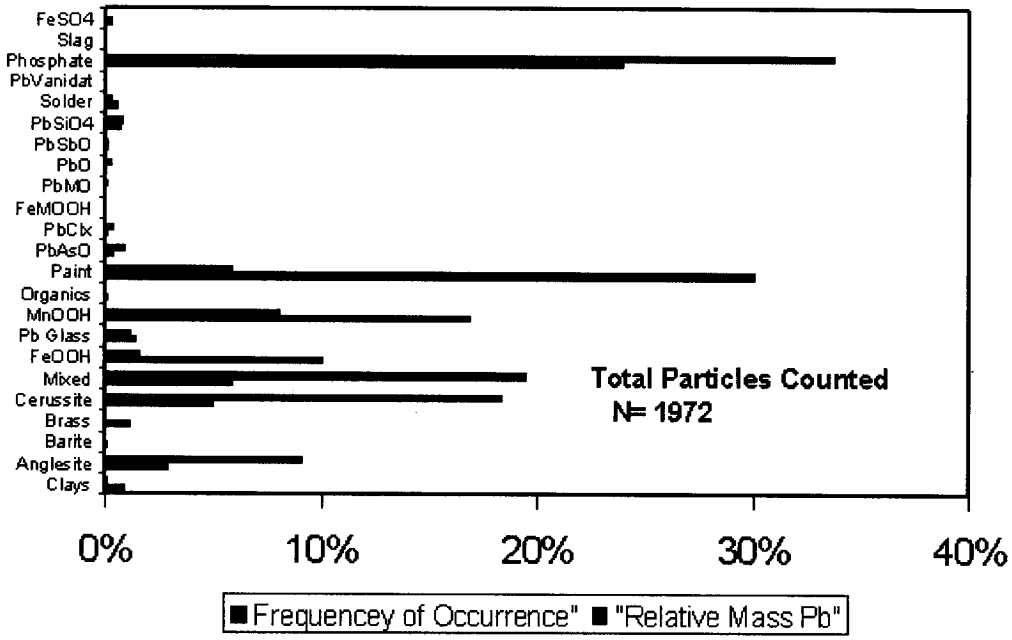
Figure 3. EPA Omaha Gould "Park" Samples



3.03 2002 Community Soils

The Community soil samples have lead masses almost exclusively (80% of the relative lead mass) dominated by phosphates, $PbCO_3$, $PbSO_4$, and a mixed lead, with minor contributions from other lead forms, Figure 4. The community soils also contain source-traceable lead forms, (slag, $PbCl_2$, PbAsO, PbMO, PbSbO, and $PbSiO_4$) providing good evidence that pyrometallurgical activity contributed to the elevated lead concentrations. Identifiable paint was found in approximately 41% of the samples speciated and only dominated the lead mass in two (7%) of the samples. Its community-wide contribution to the lead relative mass was 6%.

Figure 4. 2002 Omaha Soil Samples.



3.04 2007 Community Soils

Samples from the 2007 study have lead masses almost exclusively (78% of the relative lead mass) dominated by phosphates, $PbCO_3$, MnOOH, and $PbSO_4$, with minor contributions from other lead forms including many of the source-traceable forms found in the 2002 study, Figure 5. The particle-size distribution for all lead species is nearly log normal, Figure 6. The phosphate, $PbCO_3$, MnOOH, and $PbSO_4$ particles are small, with a median particle size of 13 microns.

In the 2007 sample set two new lead forms were found; lead tungstate ($PbWO_4$) and lead titanate ($PbTiO_3$). They exhibit no specific geographical distribution about the OLS and are not directly associated with any other lead form. Lead tungstate has a RM_{Pb} of less than 1%, and was only found in seven (14%) of the 2007 samples; however, one sample (20235-P3) contained a large amount (54% RM_P). Lead tungstate particles are liberated and small (mean 2 microns).
Lead titanate has a RM_{Pb} of 2% and was found in eight (16%) of the 2007 samples. Two samples (52426-P18 and 14788-G2) contain between 18-38% RM_{Pb}. Of these lead forms, only lead titanate has been used as a pigment and its use in this country as a house paint is likely rare. It is more likely that both lead forms represent relatively modern uses in electronics.

Figure 5. 2007 Speciation Results.

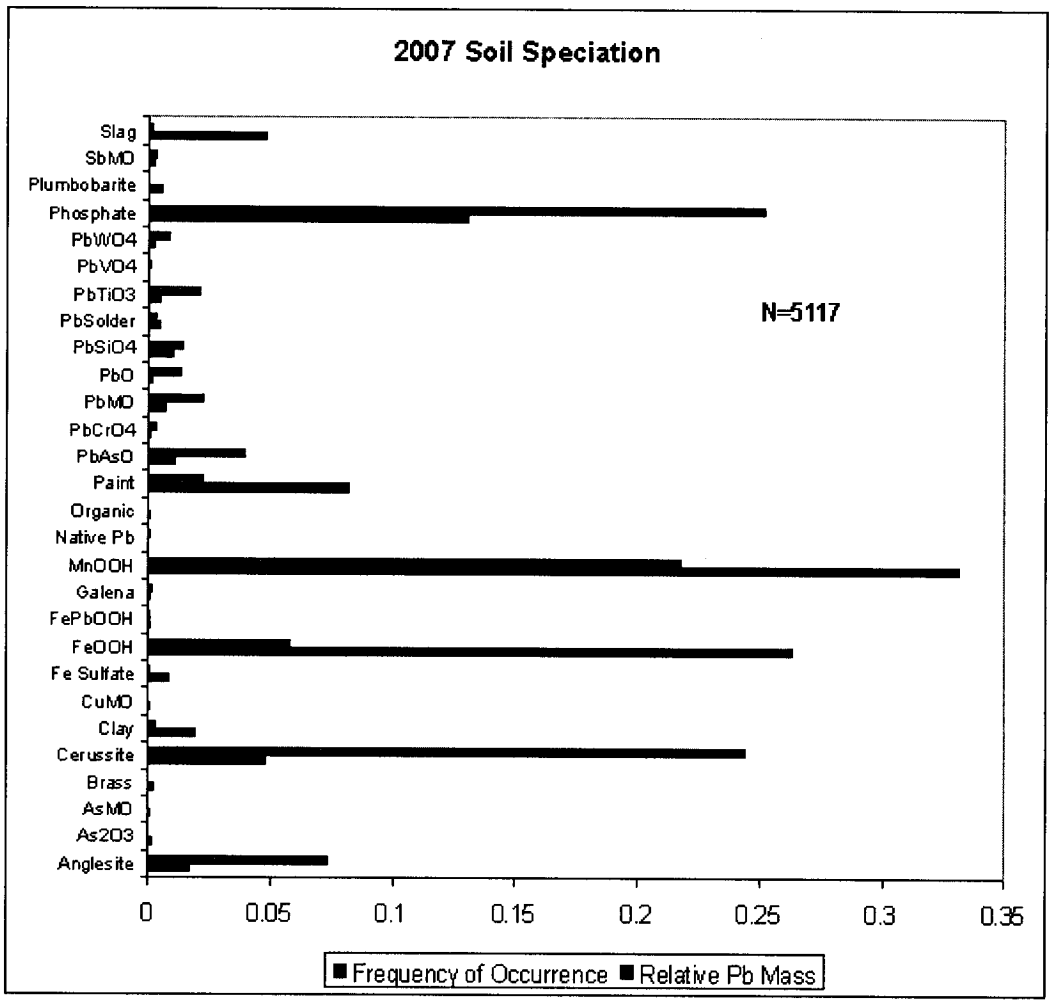
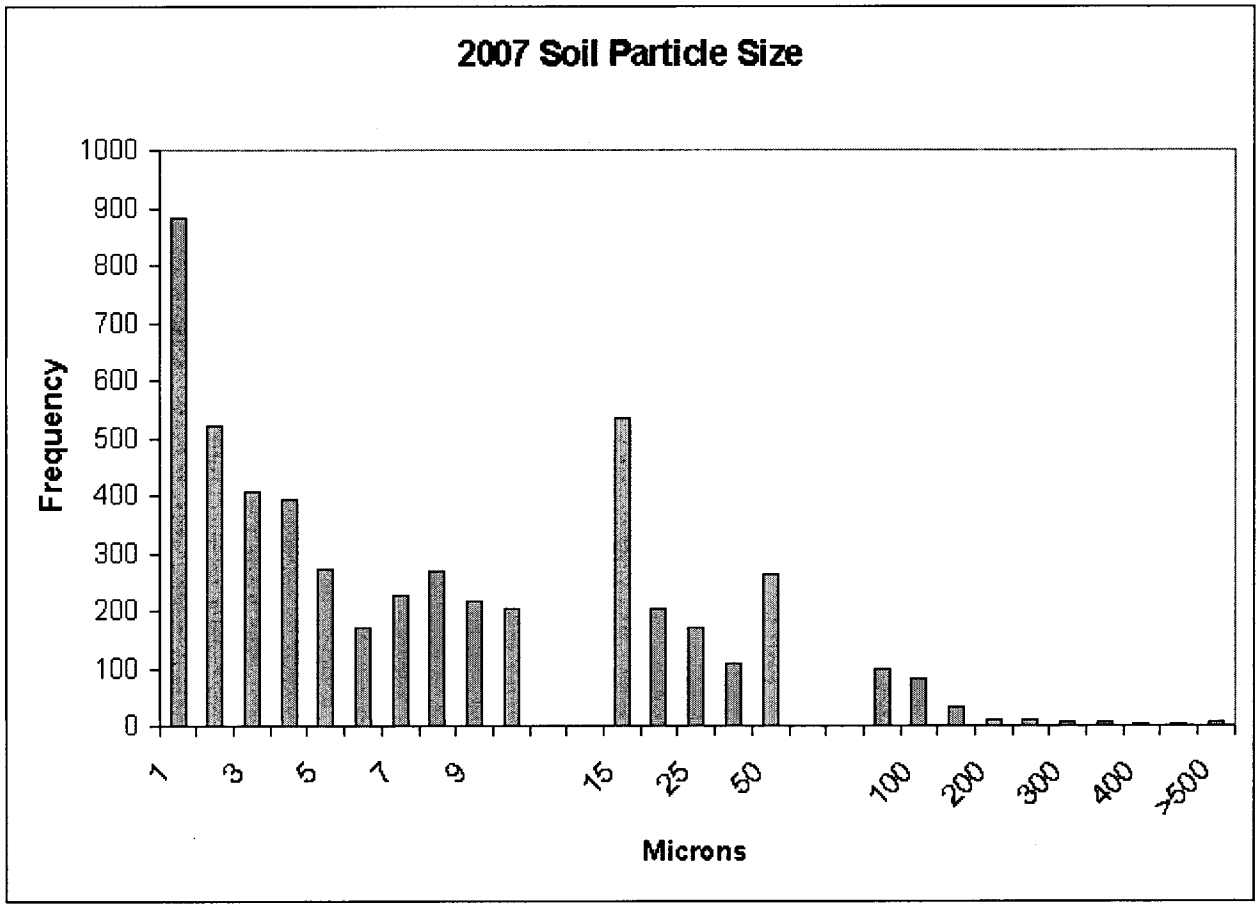


Figure 6. 2007 Lead Speciation Particle Size Distribution.



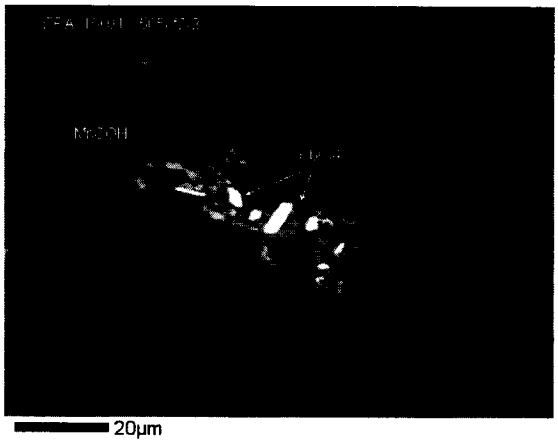
3.05 2002-2007 Community Soils

The 2007 sampling was initiated to expand the areal coverage of speciation samples within the Omaha lead site. Combining the 2002-2007 community soil sample sets (Figure 1) now provides soils with varied bulk lead concentrations (66-5788 mg/kg), averaging approximately 800 mg/kg Pb. The entire set now includes seventy-eight individual soils (4- drip zone, 28- front yard, 40- back yard, 3- park, and 3 garden).

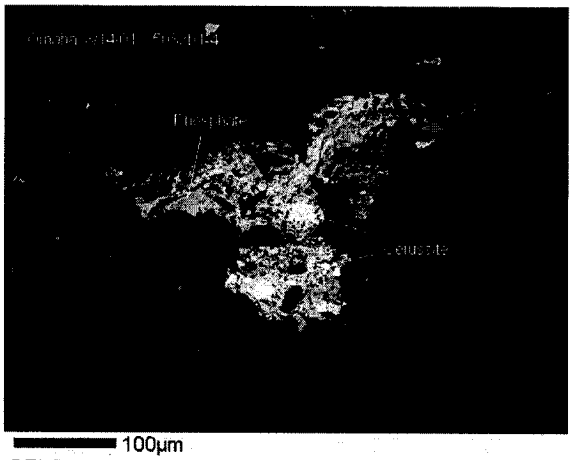
These samples have lead masses almost exclusively (83% of the relative lead mass) dominated by phosphates, $PbCO_3$, MnOOH, $PbSO_4$ and a mixed lead, with minor contributions from other lead forms, Figure 6. The particle- size distribution for all lead species is again nearly log normal, Figure 7. The phosphate, $PbCO_3$, MnOOH and $PbSO_4$ particles are small, with a median particle size of 14 microns, while the mixed lead (a combination of $PbCO_3$ + $PbSO_4$+ PbO) is generally much coarser at 280 microns. The mixed-lead phase was not found in any samples from the 2007 study and thus is not as significant a source of lead to the Site, as indicated in Figure 6. It was only found in a single sample (5063F-2) from the 2002 study.

The community soils contain source-traceable lead forms (slag, $PbCl_2$, PbAsO, PbMO, PbSbO, and $PbSiO_4$), again providing good evidence that pyrometallurgical activity contributed to the elevated lead concentrations. However, the "soil interacting" phases, Mn oxide, Fe oxide and phosphate, are more prevalent, representing a combined 49% RM_{Pb}, as is typical in developed soil environments. These phases are the result of soluble lead sorbing onto Mn, Fe, and/or P minerals

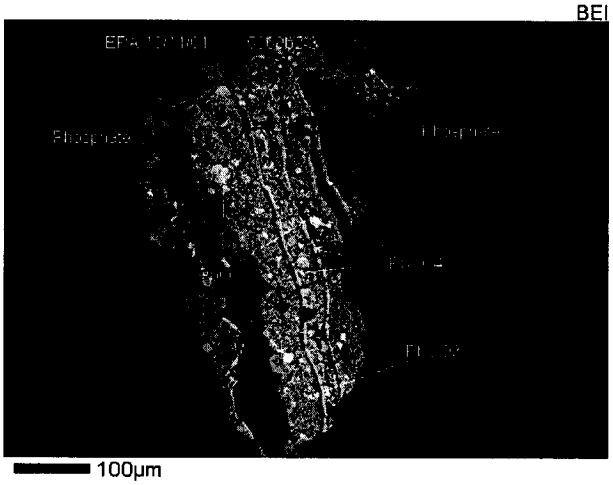
that are found in soils. Good physical evidence can be seen in photos below, supporting the transition of lead in $PbCl_2$, $PbCO_3$ and paint to these soil phases.



20μm
BEI Omaha



100μm
BEI Omaha



100μm
BEI EPA

Figure 7. 2002-2007 Speciation Summary.

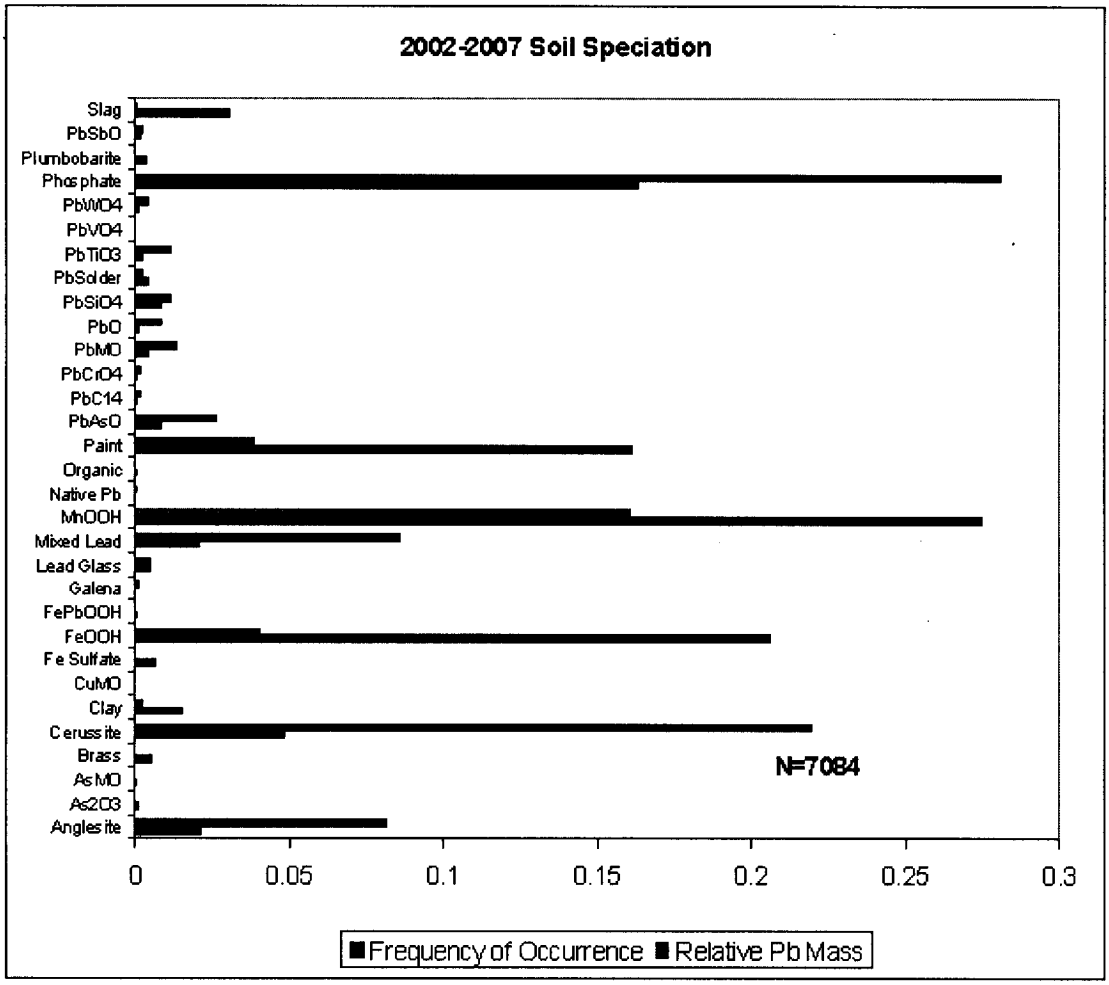
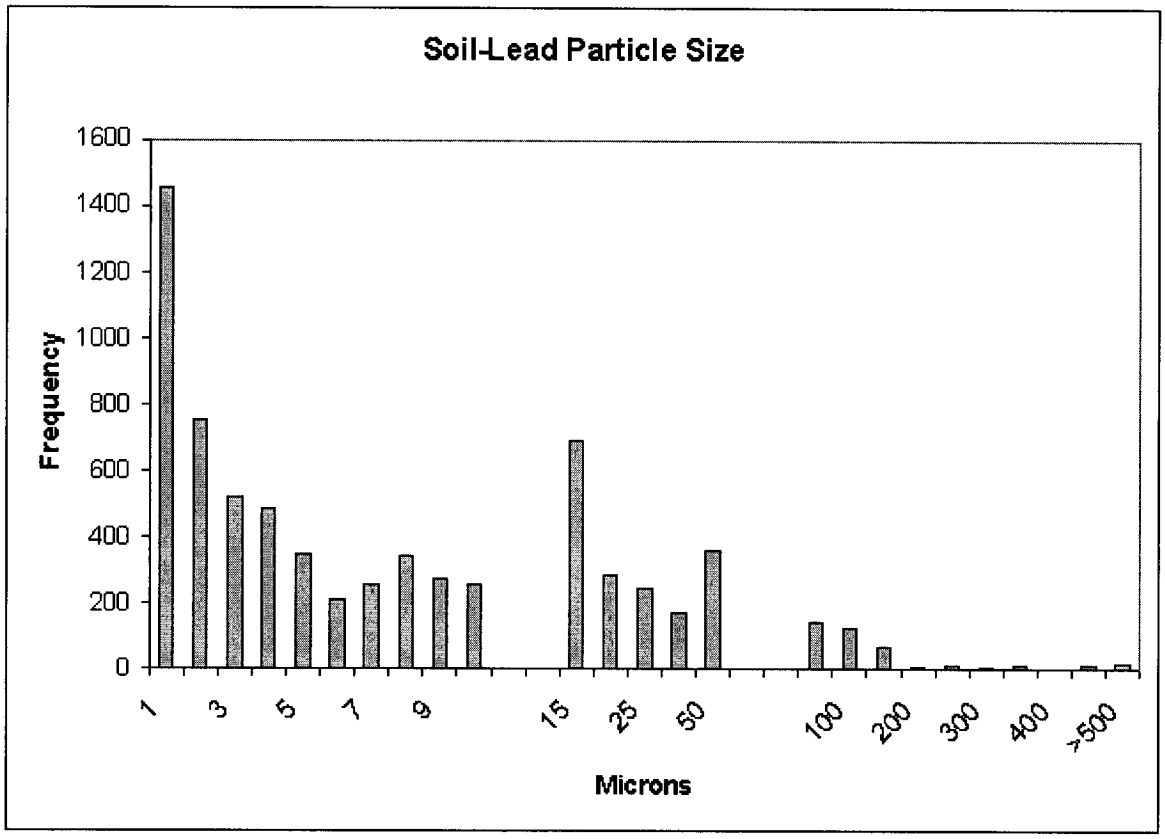


Figure 8. 2002-2007 Soil-Lead Particle Size Distribution.



4.0 STATISTICAL STUDY

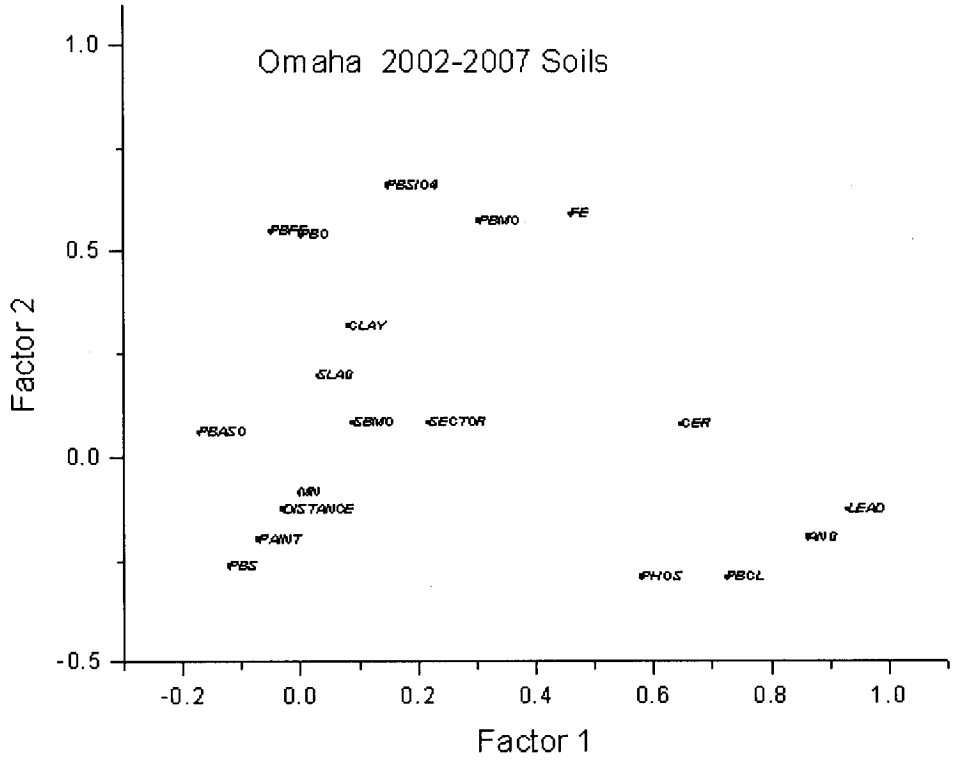
A limited statistical evaluation of the speciation results was conducted in order to determine lead phase associations within source groups and relate these associations to those found in residential soils in order to support any apportionment conclusions. Matrixes were constructed using seventeen variables and 'n' cases (depending on the number of samples) for each of the three major sample groups to determine covariance and a factor analysis, using *STATISTICA*. The variables included data from the Omaha speciation study (Min_{pb}), and bulk metals concentrations. Table 3 illustrates the results for the OLS 2002-2007 residential soils. The most significant correlations between variable pairs have been marked in **bold** in Table 3. Many of these correlations support the source categories established in this and earlier reports.

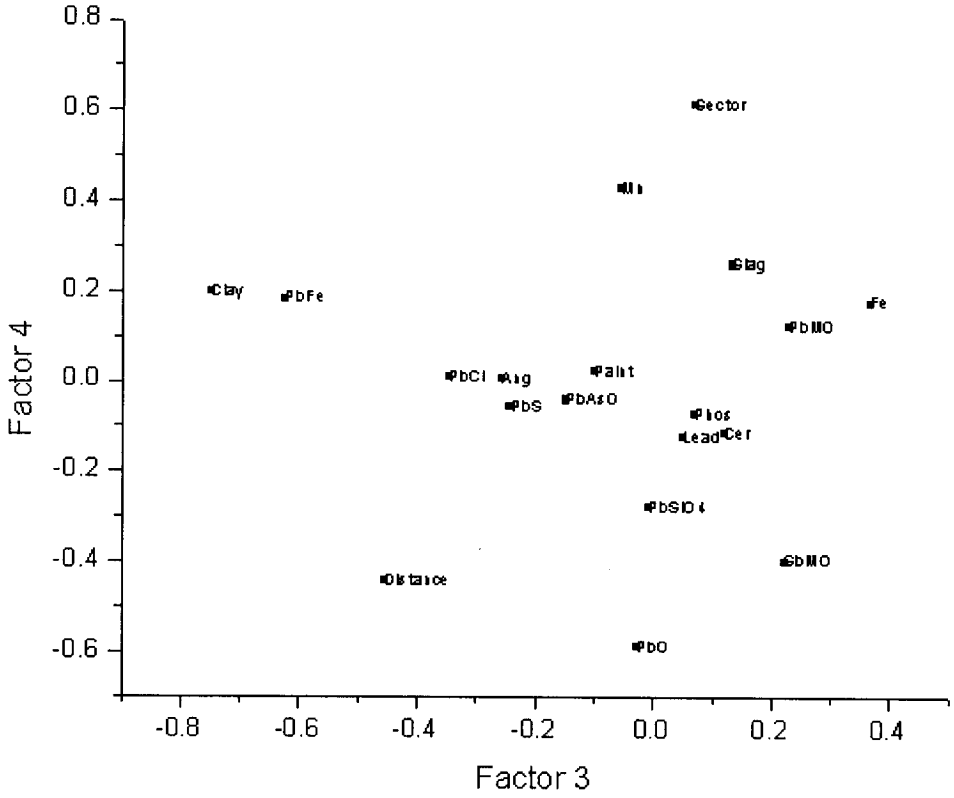
Four observations that one can make from the residential soil data, Table 3, which are most important to this study are: 1) the total lack of a significant correlation (r^2 = -.06 to -.13) between $PbSO_4$-$PbCO_3$-PbO (the three most common lead paint pigments) and the occurrence of paint. These data support the fact that the occurrence of these three phases in residential soils is most likely pyrometallurgical in origin; 2) bulk lead concentrations are most significantly correlated to the presence of $PbSO_4$-$PbCl_2$-Phosphate-$PbCO_3$ (r^2 = .66 to .84, $p < 0.05$); 3) three pyrometallurgical lead forms (PbO, PbFeO, and $PbSiO_4$) show the greatest "commonality" among the correlation variables; 4) $PbCl_2$-$PbSO_4$ and phosphate have significant correlations (r^2= 0.41-0.42, $p<0.05$), suggesting that the lead sorbed to phosphate is pyrometallurgical in origin. To further investigate the above correlations, a preliminary factor analysis study was conducted. Eight factors were identified in the data set using principal components (the number of factors

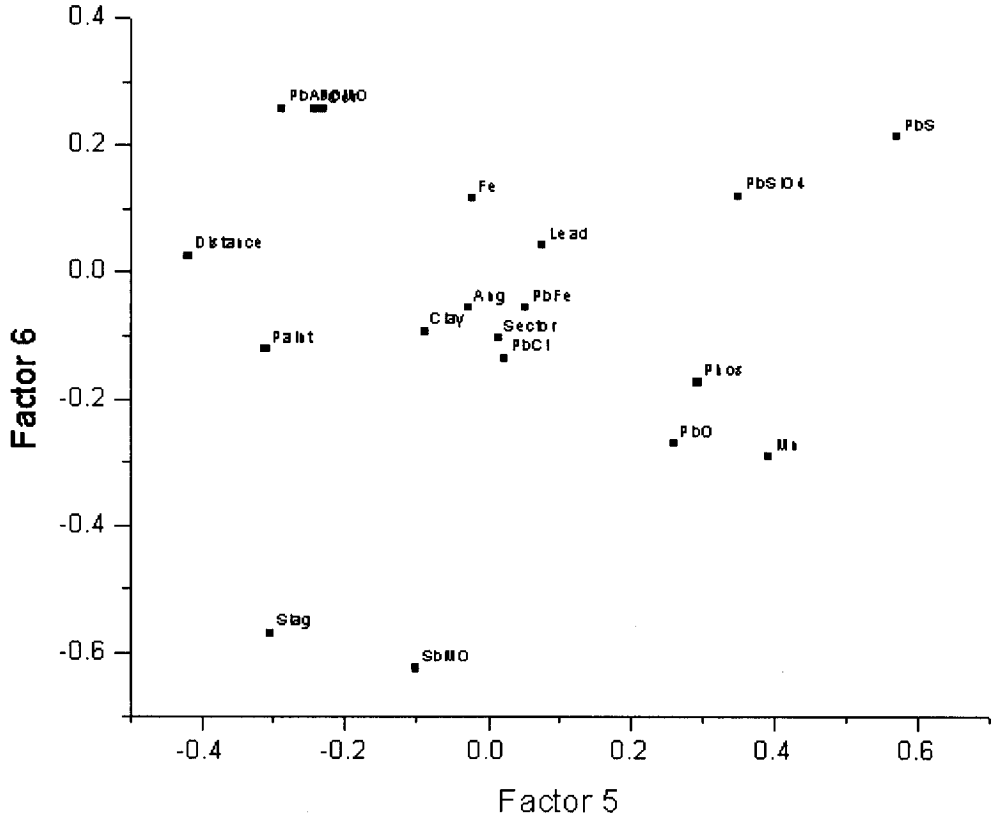
selected is determined following the Kaiser method (1960) (i.e., no eigenvalues <1.0)), accounting for approximately 71% of the variance. The factors represent lines of maximal variance about the data sets. Each consecutive factor is defined to maximize the variability not captured by the preceding factor. Factor loadings, Figure 9, graphically show a strong (>0.5 for factor loadings) co-location of the variables $PbCl_4$, $PbSO_4$, $PbCO_3$, phosphate and bulk lead accounting for 18% of the variance; $PbSiO_4$, iron oxide, and PbMO, 12%; clay and PbFeOOH 9%; PbO and sector, 8%; PbS 7%; PbSbO and slag, 7%; and paint 6%.

These data confirm that a significant percentage of the co-variance in the speciation is dominated by pyrometallurgical phases and that paint is not likely a significant factor. The co-location of phosphate with the lead phases $PbCl_4$, $PbSO_4$, and $PbCO_3$ and that of clay and PbFeOOH suggest that the lead found in phosphate and clay could most likely be derived from the weathering of pyrometallurgical-source lead phases.

Figure 9. Factor loadings for principal component analyses.




0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Factor 4
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
Factor 3
Sector
Slag
Clay
PbFe
Fe
PbMO
PbCl
Ag
PbS
PbAsO
Lead
Cer
PbSiO4
SbMO
Distance
PbO


0.4
0.2
0.0
-0.2
-0.4
-0.6
Factor 6
-0.4
-0.2
0.0
0.2
0.4
0.6
Factor 5
PbS
Fe
Lead
Distance
Arg
PbFe
Clay
Sector
PbCl
Paint
Plos
PbO
Mn
Slag

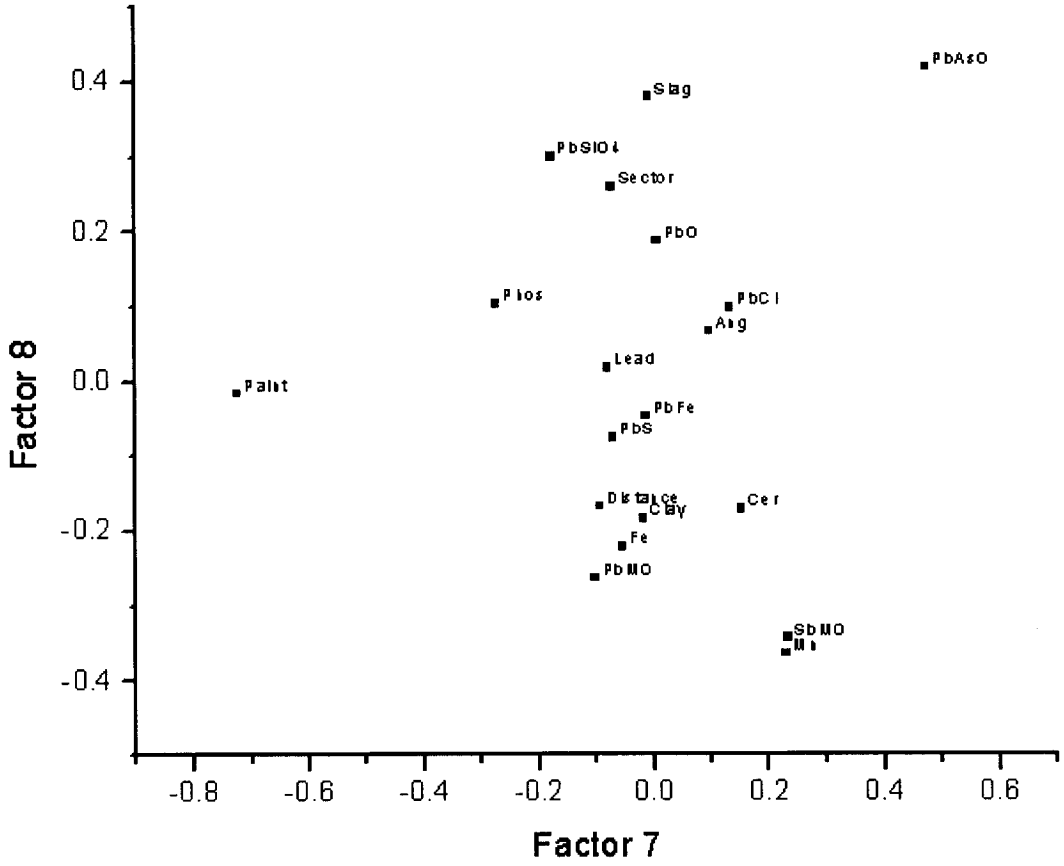

PbAsO
Slag
PbSiO4
Sector
PbO
Pios
PbCl
Alg
Lead
Paint
PbFe
PbS
Distance
Clay
Cer
Fe
PbMO
SbMO
Mn
0.4
0.2
0.0
-0.2
-0.4
Factor 8
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
Factor 7

Table 3. Correlation matrix for 2002-2007 Community Samples.

	Ang	Cer	Clay	FeOOH	MnOOH	PbAsO	PbCl2	PbFeO	PbMO	PbO	PbS	PbSiO4	Phos	SbMO	Slag	Paint	Bulk Pb
Ang	1	**0.51**	**0.35**	0.18	-0.02	-0.08	**0.89**	-0.07	0.13	0	-	-0.01	**0.42**	0.05	0	0	**0.84**
Cer	**0.51**	1	0	**0.34**	-0.16	0.1	**0.45**	-0.13	**0.3**	-0.1	0	0.05	0.21	0.14	0.1	-0.1	**0.66**
Clay	**0.35**	0	1	0.09	0.09	-0.1	**0.39**	**0.85**	0.26	0.11	--	0.08	0	-0.32	**0.51**	0	-0.01
FeOOH	0.18	**0.34**	0.1	1	0.1	-0.03	0.06	0.34	**0.57**	0.28	0	**0.43**	0.1	0.11	0.3	0	**0.36**
MnOOH	0	-0.2	0.1	0.1	1	-0.09	0.07	0.1	-0.13	-0.2	0.7	-0.06	0	0.04	-0.2	0	0.04
PbAsO	-0.1	0.1	-0.1	-0.03	-0.09	1	-0.1	-0.03	-0.05	0	--	-0.09	-0.2	-0.23	0	-0.1	-0.03
PbCl2	**0.89**	**0.45**	**0.39**	0.06	0.07	-0.1	1	-0.07	-0.07	0	--	-0.09	**0.41**	-0.18	0	0	**0.76**
PbFeO	-0.1	-0.1	**0.85**	0.34	0.1	-0.03	-0.1	1	**0.44**	**0.91**	--	**0.52**	-0.2	-0.47	**0.39**	0	-0.19
PbMO	0.13	**0.3**	0.26	**0.57**	-0.13	-0.05	-0.1	**0.44**	1	0.28	-1	0.19	0	-0.02	**0.74**	0	0.17
PbO	-0.1	-0.1	0.11	0.28	-0.19	-0.08	-0.1	**0.91**	0.28	1	--	**0.64**	0	0.72	0	-0.1	-0.02
PbS	--	-0.4	--	-0.28	0.69	--	--	--	-0.55	--	1	--	0.28	-0.35	0	-0.4	-0.09
PbSiO4	0	0.1	0.1	**0.43**	-0.06	-0.09	-0.1	**0.52**	0.19	**0.64**	-	1	0	-0.38	0	-0.1	0.18
Phos	**0.42**	0.21	0	0.09	0.03	-0.18	**0.41**	-0.19	-0.05	0	0.3	0.01	1	0.18	0	0	**0.66**
SbMO	0.05	0.14	-0.3	0.11	0.04	-0.23	-0.18	-0.47	-0.02	0.72	0	-0.38	0.18	1	0.19	-0.1	0.16
Slag	-0.1	0.1	**0.51**	0.3	-0.19	-0.07	0.01	**0.39**	**0.74**	0	0	-0.03	0	0.19	1	0.1	-0.07
Paint	-0.1	-0.1	0	-0.07	0.07	-0.14	0	-0.09	-0.08	-0.1	0	-0.13	0	-0.13	0.1	1	0.01
Bulk Pb	0.84	0.65	0	**0.36**	-0.04	-0.03	**0.76**	-0.19	0.17	0	0	0.18	**0.66**	0.16	0	0	1

5.0 APPORTIONMENT

Based on the results from the lead speciation studies (2002-2007), an attempt to apportion the total soil lead to most probable sources was made using the Min-Pb values, Table 2. Three specific categories for the apportionment were made: pyrometallurgical lead, non-specific soil- forming lead, and anthropogenic. Criteria for each of these categories were as follows:

Pyrometallurgical Lead: Slag, PbAsO, PbFeO, PbMO, $PbSO_4$, PbO, $PbCl_2$, $PbCO_3$, mixed-Pb, plumbobarite, $PbVO_4$, PbS, PbSbO and $PbSiO_4$

Soil-Forming Lead: FeOOH, MnOOH, iron sulfate, phosphate, organic, and clays

Anthropogenic: Paint, Solder, Pb-Glass, $PbTiO_2$, $PbWO_4$, $PbCrO_4$, and Brass

Pyrometallurgical and anthropogenic species were chosen based on data from site-specific, ASARCO plant and Gould park samples, metallurgical literature (Fergusson, 1990), and previous studies (USEPA 2002, 2003, and 2004; Casteel et al., 1991; Maddaloni et al., 1998; Davis et al., 1993; and Ruby et al., 1993). The soil-forming lead phases are most likely the result of solublized lead, released from the other two populations that are now sequestered (by sorption) in common, soil-forming mineral phases. Since at least some of the bulk lead found in this category has likely come from pyrometallurgical processes, a percentage of the "non-source specific" category (based on the percentage of pyrometallurgical lead identified in each sample) has been assigned to this source.

Results of the apportionment are summarized in Table 4. The apportionment calculation, based only on speciation results, indicates that on average (0-97%) a minimum of 32% of the bulk lead concentration in community yards would have had a pyrometallurgical lead source. The most common contributors to this category are lead carbonate, lead sulfate, and lead oxide. Although these forms of lead represent nearly 50% of the RM_{Pb} at the ASARCO site, they have also been historically used as lead pigments in house paint. The author has made an adjustment, Table 4, to the contribution of these lead forms to lead paint, based on the presence of paint in a sample; however, paint is seldom found in samples of the OLS. Additional morphological evidence suggesting these forms of lead are not from paint is their particles-size. In the community soils, these lead forms, $PbCO_3$, $PbSO_4$, and PbO, have average particle sizes of 16, 12, and 12 microns, respectively. These particle sizes are an order of magnitude greater than those used by the paint-pigment manufacturers of 0.4-1.3 microns (Patton, 1973; Mattiello, 1942; and Dunn, 1967). Finally, isotopically it is difficult to exclude lead paint from being a contributor to the OLS, but a careful look at the data does suggest that paint plays a limited role. Paint-lead isotopic values, Figure 10, from homes in the OLS (UP, 2006) cover a broad range, overlapping the values for the ASARCO facility (area including ASARCO lead source locations: Mexico, Colorado, Montana and Utah). However, even though paint samples cover a 300% greater range in isotopic values, only 21% of the OLS soils have values outside of the ASARCO range. In addition, the lead market for paint pigment during much of this time period was becoming dominated by lead from the Missouri District. This factor would significantly limit paint's contribution to OLS soils. The data in Figure 10b (Drexler, 2002), support the limited impact of gasoline and Gould (Park) as a source of lead to the OLS.

Thus, the pyrometallurgical proportion is most likely to exceed 62% on average, since at least half of

the "non-specific source" lead could be attributed to pyrometallurgical activity, as the lead isotopic and statistical data suggests. More than 90% of the community soils studied contained pyrometallurgical lead.

Figure 10. Lead isotopic data for the OLS and lead sources. Data from literature and (UP, 2006 and Drexler, 2002).

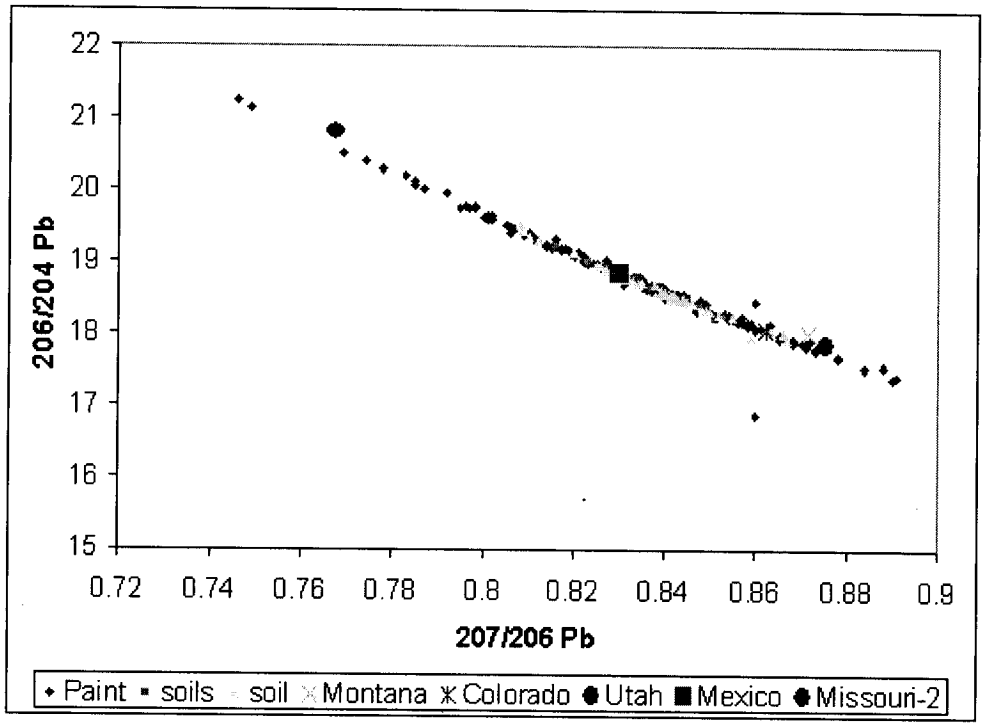
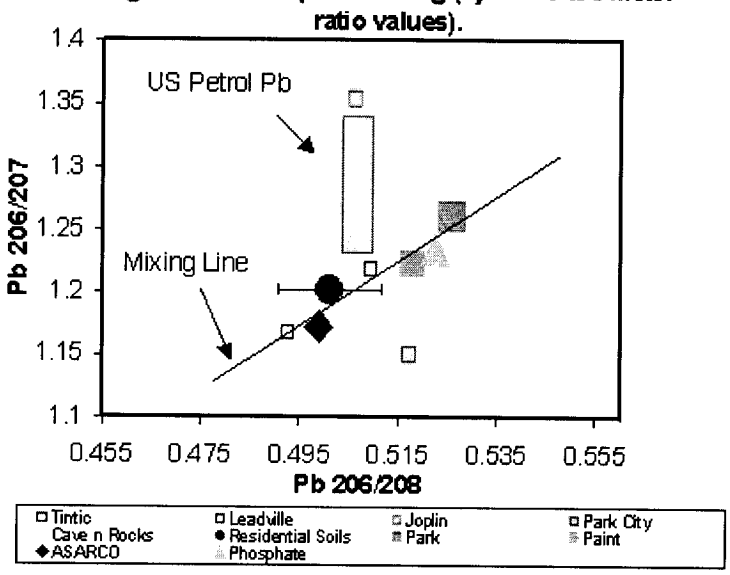


Figure 10b. Isotopic Sourcing (symbols are mean ratio values).



Non-source specific sources of lead are the most abundant, ranging from 0% to 100% and averaging 59% of the bulk lead. Leaded phosphate comprises 60% of this category on average, Table 4, and as indicated previously, morphological evidence shows that some phosphate lead can be traced to ASARCO as a source. Other possible sources to the lead in this category include the anthropogenic sources listed above, and lead from gasoline.

The anthropogenic sources only account for 9% of the bulk lead in the OLS. One sample has the combination of As_2O_3 (arsenic trioxide) and PbAsO. Since none of the pyrometallurgical sources in the area produced arsenic trioxide, it is most likely this sample has been contaminated with a herbicide.

6.0 CONCLUSIONS

Based on my work as reflected in the 2002 and 2007 Speciation Reports and the 2007 Emissions Report (Medine et al., 2007), I have reached the following conclusions with respect to the occurrences of lead found in residential soils from the Omaha area:

- Pyrometallurgical forms of lead are the largest identifiable lead source in residential yards:

  Yards having "fingerprinting" phases (PbMO, $PbCl_2$, Slag, PbFeO, $PbSiO_4$, and PbAsO), attributable to a pyrometallurgical source, and these phases are common to the ASARCO plant and are not associated with other identified sources.

- The ASARCO facility's historical emissions clearly dominate all other identified sources.

- More than 90% of yards speciated have pyrometallurgically apportioned lead .

- At least 32% of the bulk lead found in community soils is from a pyrometallurgical source.

  However, this is clearly a minimum since most of the lead (59%) is found in non-source specfic forms which have sorbed their lead from the weathering of more soluble lead forms. Given lead particle morphologies, as demonstrated in above photomicrographs, much of this lead could have come from ASARCO related material.

- A strong lead isotopic correlation between community soils and ASARCO plant with apparent limited input from Gould or leaded gasoline. Lead paint can not be isotopically ruled out as a source of lead, but isotopes do suggest its significance is also limited.

Based on my analytical work and data reviewed, as cited herein, it is my opinion that the lead in the OLS is primarily the result of both smelter emissions and lead-bearing paint. Further, it is my opinion that the primary non-anthropogenic (as defined in this report) source is the ASARCO smelter facility.

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APPENDIX A

Drexler Vita

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B.S., Western Illinois University, 1976 (Geology-Chemistry)
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Chairman of Technical section, "Calc-Alkaline volcanism at Plate Margins" Geol. Soc. Amer. National Meeting, Reno, Nev. 1984.

Co-Chairman of Symposium, "Laramide volcanism in and around Colorado",Geol. Soc. Amer. Rocky Mountain Section, Boulder, Colorado, 1987.

Co-Editor Colorado School of Mines Quarterly Special Volumes "Cenozoic Volcanism in the Rocky Mountains- an Update" Vol.82 #4, 83 #1, and 83 #2 1988-1989.

Environmental Protection Agency's Technical Advisory Committee for the Leadville, Colorado CERCLA site. 1990-1993.

Environmental Protection Agency's Advisor to the Technical Advisory Committee for the Aspen, Colorado CERCLA site. 1992.

Invited speaker:

U.S. EPA Mine, Milling, and Smelter Waste Seminar, August, 1994.

U.S. EPA Lead Risk Assessment and Remediation Large Area Lead Sites Workgroup, April, 1995.

US EPA Workshop on Modeling Lead Exposure and Bioavailability, August, 1998.

NEPI 'Protecting Children's Health: Assessing the Relationship of Soil Lead to Blood Lead' Washington, DC.)Ctober 27-28, 1998.

ITRC Conference 'New Environmental Technologies and Market Opportunities' San Antonio, TX. October, 19, 2000

USEPA Workshop Metals Assessment Issue Papers Washington, D.C., December 16-17, 2002.

USEPA Workshop Bioavailability estimations by in vitro techniques Tampa, Fl., April 14-17, 2003.

CALEPA Workshop on Bioavailability characterizations using In Vitro and EMPA Techniques Sacramento, CA.September 13, 2005.

New York Childhood Lead Conference: Techniques for Determination of Lead Bioaccessability and Fingerprinting. October, 7, 2005.

Professional Experience:

Since 1989 I have been working extensively with the EPA on Superfund remediation of heavy metal mining, smelting, and milling sites including: Leadville, CO., Aspen, CO. Midvalle, Utah., Sandy City, Utah, Anaconda and Butte, Montana, Omaha, Nebraska, El Paso, Texas, Herculaneum, Missouri, Couer de Lane, Idaho, and Kennecott Utah.

1982 to present faculty member in the Department of Geology at University of Colorado. I supervise and maintain the departments analytical facilities, including a JEOL 8600 automated electron microprobe with four wavelength dispersive detectors and energy dispersive capabilities, two Kevex 0700 automated XES x-ray fluorescence system, a PHILIPS PW1730 WDS x-ray fluorescence system, a ISI SX30 SEM with a KEVEX energy dispersive analyzer and image analyzer, a Fluid Inc. gas-flow heating and cooling stage, VARIAN Ultra Mass and Perkin Elmer DRC-e Inductive-coupled mass spectrometers with CETAC LSX-200 laser abaltion, a DIONEX 4500i ion chromatography system, a ARL 3410 Inductive-Coupled Plasma, a Hewlett-Packard 5890/5971 GC Mass Spectrometer, and GIS workstation. The laboratories average operating budget is $150,000/yr with management responsibility of 2.4 FTE's.

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Selected Technical Reports for Private Companies:

1982 Silver and Gold concentration in mineral concentrate, U.S. Minerals.

1983 Pyrite concentrations in mineral processing samples, IntraSearch.

1984 Silicate contamination as a cause of hard-disk failure, Amcodyne.

1985 Zinc plating on mass spectrometer walls; a source of contamination, Masstron.

1985 Synthetic glass and its morphology, Tetra Tech Inc.

1985 Characterization of Indian Potery for correlation studies, Gilbert and Commonwealth.

1986 Silver mineralization in copper sulfide deposit, Jack Bright Geological.

1986 Platnoid mineralization potential of Kennet Mine, Montana, IntraSearch and Au-Ag Resources.

1987 Platnoid mineralization in placer sands, Dallas, Texas, SELCO.

1987 Evaluation of Equity Mine, Colorado for Crown Resourses.

1988 Lead contamination at rock wool plant, Water, Waste and Land Inc.

1988 Gold-silver mineralization from the Manhattan Mine, Echo Bay Minerals Company.

1989 Lead-Arsenic mineralogy from soil-rat studies by PTI Environmental Services.

1989 Lead contamination from Midvalle toxic waste site, Camp Dresser and McKee Inc.

1990 Lead contamination from Midvalle, Utah, Superfund Site, U.S. Environmental Protection Agency.

1990 Lead contamination at Bunker Hill, Idaho, XXXXXX Environmental Services, p. 1-82.

1990 Lead speciation in samples from Bunker Hill, Idaho, XXX Corporation.

1991 Lead speciation in paints, PTI Environmental Services.

1992 Heavy metal speciation in aggregate from vitrification process. Department of Justice

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1992 Heavy metal contamination and bioavailability of mine waste from the Smuggler Mine, Aspen, CO. Camp Dresser and McKee and URS Consultants.

1993 Heavy metals (Cr, Pb, Zn)characterization in contaminated soils in and around an industrial plating factory. Camp Dresser and McKee.

1993 Arsenic and lead speciation at Midvale OU2 Superfund site, Midvale, Utah. SVERDRUP.

1993 Arsenic spectiation from smelter contaminated soils, Murray, Utah. Roy F. WESTON.

1994 Metal speciation for the California Gulch CERCLA site, Leadville, CO. Camp Dresser and McKee.

1995 Findings of Metal Speciation Investigation at the California Gulch NPL Site, USEPA-WESTON.

1996 Hazardous Wastes from metal refineries: The use of iron filings as a treatment, long-term effectiveness, environmental factors, and effects on TCLP. Environmental Protection Agency.

1996 Characterization of paint and ink wastes in soils, heavy metal (Cr, Pb) speciation. The Weinberg Group.

1997 Speciation of lead from paint, smelter and tailings sources in residential soils at Tar Creek, Ok. U.S. Bureau of Land Management.

1998 Arsenic and lead speciation of contaminated soils: their sources, smelter(s), paints, insecticides, or auto emissions? Colorado Department of Public Health.

2000 Arsenic and lead speciation of contaminated soils from the Vasquez Boulevard and I70 Site, Denver, Colorado: their source(s); smelter(s), paints, or insecticides? USEPA Region VIII.

2002 Source attribution of lead from contaminated residential soils in central Omaha, Nebraska. A speciation and LA/ICP/MS study. USEPA Region VII.

2002 The history, development and use of in vitro techniques for assessing lead biaavailability: A critical review. USAHPPM.

2003 Source attribution of lead from contaminated residential soils in El Paso, Texas. A speciation and LA/ICP/MS study. USEPA Region VII.

2005 Source attribution of lead from contaminated residential soils in Herculaneum, Missouri. A speciation and LA/ICP/MS study. USEPA Region VII.

EXPERT TESTIMONY:

(1985?) XX vs Stanley Tool Company
Denver Civil Court (Settlement)

(1990) US vs Sharon Steel, Midvale, UT.
EPA Attorney Matt Coehn (Ruling for US)

(1992) US vs ASARCO and Resurection Mining, Leadville, CO.
DOJ Attorney Jerry Elington (Settlement)

(1991) US vs Marine Shale
DOJ Attornies Tom Clark and Bruce Buckheit
(Ruling for US)

(1994) People vs ANZON
Class action suite in Port Richmond,PA. Richard Lewis attorney: Cohen, Milstein, Hausfeld and Toll, Washington, D.C.
(Settlement)

(1995) Harding Vs Browning-Ferris
Joanne Grossman attorney: Covington and Burling, Washington, D.C.
(Settlement)

(1995) US vs Sloan Valve
Laura Whiting attorney: EPA Dallas, Tx.
(Settlement)

(1995) US vs NIBCO
Laura Whiting attorney: EPA Dallas Tx.
(Settlement)

(1993-98) US vs ARCO
DOJ Attorney Lynn Dodge (Settlement)

(1997-99) Neztsosie vs Rare Earth Metals
Bernstein Littowitz, Berger, & Grossmann
(Settlement)

(1997-98) US vs ARCO (Bingham Creek)

DOJ Attorney Jerry Ellington
(Settlement)

(1998-99) People vs ASARCO (Corpus Christi, Tx)
Slack and Davis
(Settlement)

(2000?) People vs ASARCO (Globeville, CO)
Court Expert
(Settlement)

(2006) Banks et al., vs Sherman Williams
Davis and Feder
(Active)

(2006) City of Milwaukee vs. Sherman Williams
CMHT
(Active)

(2007) US vs. ASARCO
DOJ
(Active)

All cases principally involved my expertise in "metal speciation": characterization of inorganic contaminants and how they impact bioavailability and bioaccessability.

RATES:

Research projects are negotiated based on total project deliverables, and generally reflect reduced hourly rates.

Consultation $60/hr plus expenses
Deposition and trial $400/hr.
* All travel time is charged at a $40/hr rate

	Bulk Pb	**554**	**270**	**576**	**836**	**818**	**782**	**588**	**477**	**458**	**508**	**1377**	**408**	**399**
		52426-P18	20235-P3	14788-G	17503-G	52129-F2	51457-F2	49528-F2	45862-F2	35787-F2	26243-F2	24505-F2	11897-F2	47533-F1
Pyrometallurgical														
	Barite	1	1	1		1	1							
	Cerussite	27	2	63		18	31	22		7		251	25	
	PbAsO			4					18				2	
	Pb Vanidate													
	PbCl4													
	PbS		4									17		
	PbFeOOH								2					
	PbMO		1	3	22		2				24	20		
	PbO			163		5								
	PbSbO		3								2	2		
	Slag													
	PbSiO4			2		1								
	Mixed Lead													
	Anglesite				7			24	7					
		28	11	236	29	25	34	46	27	7	26	290	27	0
Less Paint Factor (~50% of Paint Min-Pb)						18	31			6				
		0.051	0.041	0.410	0.035	0.031	0.043	0.078	0.057	0.015	0.051	0.211	0.066	0.000
Pyrometallurgical contribution to		21	4	50	28	15	27	41	25	7	25	229	25	0
Non-Source Specific Lead														
Total Pyrometallurgical		49	15	286	57	22	30	87	52	8	51	519	52	0
% Pyrometallurgical of Total Pb		9%	6%	50%	7%	3%	4%	15%	11%	2%	10%	38%	13%	0%
Non-Source Specific														
	Clay	1		3	3				1				2	6
	FeSO4	1			1				1		1	1		
	Fe Oxide	38	16	25	70	4	10	13	14	43	64	12	8	15
	Mn Oxide	43	86	46	409	371	250	194	322	267	305	257	142	378
	Organics													
	Phosphate	328	4	47	325	112	365	316	112	130	111	816	229	
Total Non-Source Specific		411	106	121	808	487	625	523	450	440	481	1086	381	399
% Non-Source Specific of Total Pb		72%	38%	13%	93%	60%	80%	82%	89%	96%	90%	62%	87%	100%
Anthropogenic														
	Pb Glass													
	PbCrO4		5											
	PbWO4	4	146			20								
	PbTiO2	101		218										
	Paint					287	115			12				
	Solder	2	2				9	18			2			
	Brass	1												
	Herb/Rodenticide													
Total Anthropogenic		108	153	218	0	307	124	18	0	12	2	0	0	0
% Anthropogenic of Total Pb		19%	57%	38%	0%	38%	16%	3%	0%	3%	0%	0%	0%	0%

270	**351**	**525**	**655**	**2234**	**1475**	**874**	**402**	**1032**	**1585**	**502**	**485**	**585**	**375**	**618**	**560**	**595**
32101-F1	31738-F1	29530-F1	29332-F1	29245-F1	22535-F1	16423-F1	34955-DZ	52352-B2	49058-B2	44892-B2	34955-B2	29737-B2	29524-B2	29199-B2	29140-B2	29084-B2
1							1			1		1				
			27	767	1179	71	16		1454		29	3	216	4	49	
	1			9				0*						9		
	5								8							
							6									1
2	4		18	120	4	1		1			39		28	3	29	
	2	5	14	57			1					11		8	6	
					1		1		1							
							80				41	4	4			
			21	261	5					5						
3	12	5	80	1214	1189	72	105	1	1463	6	109	19	248	24	84	1
	0						9		12			3				
0.011	0.034	0.010	0.122	0.543	0.806	0.082	0.261	0.001	0.923	0.012	0.225	0.032	0.661	0.039	0.150	0.002
3	11	5	70	554	225	63	65	0	91	6	85	17	85	23	71	1
6	23	10	150	1768	1414	135	161	1	1542	12	194	33	333	47	155	2
2%	7%	2%	23%	79%	96%	15%	40%	0%	97%	2%	40%	6%	89%	8%	28%	0%
	1						10			2	10	5	3	1	11	3
1	1	1	1	1	1	8	1			1	1			1	1	1
42	24	63	34	217	49	201	57	30	54	16	62	29	30	143	43	78
94	126	288	489	295	141	310	89	71	45	186	166	36	75	203	249	164
132	170	169	52	507	88	248	92	120		293	138	454	21	243	172	350
269	322	521	576	1020	279	767	249	221	99	498	377	524	129	591	476	596
98%	88%	98%	77%	21%	4%	81%	48%	21%	1%	98%	60%	87%	11%	91%	72%	100%
							31									
					7											
						35						3				
	18						17		23			29				
					1							11		5		
											1		1	1		
								811								
0	18	0	0	0	8	35	48	811	23	0	1	43	1	6	0	0
0%	5%	0%	0%	0%	1%	4%	12%	79%	1%	0%	0%	7%	0%	1%	0%	0%
							*Sample 52352-B2 has unique mineralogy (ie. As2O3 +PbAsO) suggesting a herbicide.									

																				TABLE 4. Om
431	**455**	**452**	**892**	**464**	**468**	**423**	**863**	**306**	**3669**	**745**	**738**	**530**	**888**	**836**	**976**	**825**	**446**	**488**	**273**	**374**
24887-B2	11414-B2	48698-B1	48007-B1	46631-B1	32384-B1	34234-B1	32733-B1	32508-B1	31808-B1	28681-B1	26239-B1	25656-B1	23626-B1	17503-B1	15815-B1	10176-B1	28681-DZ	17503-DZ	12608-F1	5008B-1
			1			1			3				0	0	0		0	0		0
		33	11				72		1327		5		9	6	434	624	16		106	0
				6				7												0
58																				0
																				0
										5									2	
13	3			4			5													0
	126			5	9		1	17	217		15	20		9		30	202	21		0
	94																			0
				9			3		1	19	1	2	3		5		2			0
										43							2	0	1	0
		44		125			112		164		11	32					11	12	1	0
																				0
	50		4	47				3	642			10	2		77	39			132	0
71	273	77	16	196	9	1	193	27	2354	67	32	64	14	15	516	693	233	33	242	0
			15				18		16	0							16			
0.165	0.600	0.170	0.018	0.422	0.019	0.002	0.224	0.088	0.642	0.090	0.043	0.121	0.016	0.018	0.529	0.840	0.522	0.068	0.886	0.000
90	107	21	9	106	9	1	141	25	723	46	31	30	6	14	243	106	87	31	29	0
161	380	98	10	302	18	2	316	52	3061	113	63	94	20	29	759	799	304	64	271	0
37%	83%	22%	1%	65%	4%	0%	37%	17%	83%	15%	8%	18%	2%	4%	78%	97%	68%	13%	99%	0%
32	7	35	6	10		4	7				10	1			7					0
		1		1	1			0	1	0	1		0	1	0	0	0	1		0
	33	27	93	31	68	3	76	35	464	82	109			33	25	40	21	74	1	0
207	82	57	64	148	388		252	141	58		382			175	46	18	38	213	20	0
																		1	12	0
310	56	2	360	60	3	369	297	103	604	426	204	244	392	588	381	68	107	166		374
549	178	122	523	250	460	376	632	279	1127	508	706	245	392	797	459	126	166	455	33	374
59%	15%	22%	59%	30%	96%	88%	59%	83%	11%	62%	92%	82%	98%	94%	22%	3%	25%	87%	0%	100%
																				0
									129	36										
										8				18		2				
		253		20		47													1	
			354				36		32	120							32			0
17	6						2	0	27	4			1	6	1	2	1			0
				1									0	0			0			0
17	6	253	354	21	0	47	38	0	188	168	0	0	1	24	1	4	33	0	1	0
4%	1%	56%	40%	5%	0%	11%	4%	0%	5%	23%	0%	0%	0%	3%	0%	0%	7%	0%	0%	0%

aha Lead Apportionment.																TABLE 9. Omaha Lead Apportionment.					
659	**485**	**355**	**142**	**304**	**2080**	**332**	**334**	**415**	**785**	**1649**	**261**	**534**	**841**	**328**	**328**	**436**	**365**	**1269**	**1240**	**986**	**572**
5017F-1	5020B-2	5034B-1	5041B-1	5044B-1	5046DZ	5048B-2	5055F-1	5056F-2	5059B-1	5060B-2	5061F-2	5063F-2	5079B-2	5080B-2	5080B-2-Dup	5081F-2	5082B-1	5083B-1	5083DZ	5086B-1	5087G
0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0
355	0	9	26	24	27	18	5	0	4	81	0	67	2	0	5	162	0	252	708	103	4
0	0	0	0	62	0	0	0	0	0	0	0	0	0	60		0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	0	0	0	0	0
0	0	0	0	0	6	0	0	0	0	0	0	0	0	0		14	0	0	0	8	1
0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	0	0	0	0	0
0	0	0	0	0	2	54	3	0	0	0	0	0	0	0		0	0	0	0	9	0
0	0	0	0	0	0	0	0	0	0	0	0	0	61	0		0	0	0	0	0	0
0	0	6	0	4	0	0	0	0	0	0	0	0	0	23	2	7	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1
1	0	8	0	5	4	0	6	0	5	1	0	0	167	0	7	0	24	0	0	1	0
0	0	0	0	0	0	0	0	0	0	1097	0	168	0	0		0	0	0	0	0	405
32	0	0	0	0	0	0	0	0	0	0	0	28	2	0		1	0	117	192	0	0
388	0	24	26	96	39	72	14	0	10	1179	0	263	235	83	15	184	24	369	900	121	411
	0				21	3				40		3	3			19		85	1	8	2
0.589	0.000	0.068	0.183	0.316	0.019	0.217	0.042	0.000	0.013	0.715	0.000	0.493	0.279	0.253	0.046	0.422	0.066	0.291	0.726	0.123	0.719
159	0	21	21	66	37	56	13	0	10	279	0	131	90	62	14	91	22	212	247	104	115
547	0	45	47	162	55	125	27	0	20	1418	0	391	322	145	29	256	46	496	1146	218	524
83%	0%	13%	33%	53%	3%	38%	8%	0%	3%	86%	0%	73%	38%	44%	9%	59%	13%	39%	92%	22%	92%
1	0	2	0	1	9	0	0	0	12	1	0	0	1	0		0	0	3	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	1	0		0	0	0	0	0	1
3	14	11	8	26	29	35	1	3	63	12	35	5	40	31	9	14	32	6	11	74	3
180	11	21	0	117	118	0	134	35	352	18	116	109	31	127	126	24	202	97	41	191	8
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1	0	0	0	0	0
87	72	282	107	64	1838	221	183	146	350	360	110	152	249	86	175	177	108	622	288	585	148
271	97	316	115	209	1994	256	318	184	777	391	261	266	322	244	310	216	342	728	340	850	160
17%	20%	83%	67%	47%	95%	61%	91%	44%	97%	9%	100%	26%	28%	56%	90%	33%	87%	47%	7%	76%	8%
0	0	0	0	0	0	0	0	0	0	0	0	0	281	0		0	0	0	0	0	0
0	388	0	0	0	42	5	0	231	0	79	0	6	5	0		37	0	171	1	15	4
0	0	16	0	0	6	0	0	0	0	1	0	0	0	0	2	1	0	0	0	0	0
0	0	0	0	0	0	0	3	0	1	0	1	0	0	1		0	0	0	0	0	0
0	388	16	0	0	48	5	3	231	1	80	1	6	286	1	2	38	0	171	1	15	4
0%	80%	5%	0%	0%	2%	2%	1%	56%	0%	5%	0%	1%	34%	0%	1%	9%	0%	13%	0%	1%	1%

66	**1289**	**5788**	**1129**	**1080**	**637**				
5098B-2	1683	11509	1584	1627	5088F-2				
0									
0	822	1056	0	79					
0	94	0	0	0					
0									
0	3	66	19	0					
0									
0									
0									
0									
0									
65									
0	82	526	0	0					
0	35	2691	7	0					
65	1036	4339	26	79	0				
	4	18	7	14					
0.985	0.804	0.750	0.023	0.073	0.000				
0	196	1050	22	67	0				
65	1229	5371	41	131	0			Average	Stdev
98%	95%	93%	4%	12%	0%			32%	34%
0	0	9	0	0					
0	0	0	0	0	18.8				
0	7	33	48	41	29.8				
0	69	163	307	146	26.8				
0									
0	169	1196	618	729	561				
0	244	1401	972	916	636			Average	Stdev
0%	4%	6%	85%	80%	100%			59%	34%
0									
0	8	35	124	27					
0	0	13	7	59					
1									
1	8	48	131	86	0			Average	Stdev
2%	1%	1%	12%	8%	0%			9%	18%