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Environmental Impact of the Contact and Sonoma Mercury Mines on Water, Sediment, and Biota in Anna Belcher and Little Sulphur Creek Watersheds, Sonoma County, California

By James J. Rytuba, Roger L. Hothem, Jason T. May, Christopher S. Kim, David Lawler, and Daniel Goldstein

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Abbreviations, definitions, and datum used

Vertical and horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27 CONUS).

DOC, dissolved organic carbon

DOM, dissolved organic matter

EE/CA, Engineering evaluation/cost analysis for “non-time-critical removal actions,” as defined by the U.S. Environmental Protection Agency’s Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Hg, generic shorthand for mercury; does *not* denote speciation.

Hg_T, total mercury (inorganic plus organic).

Hg_F, total mercury (inorganic plus organic) in a filtered sample (either 0.1 mm or 0.45 mm, as specified in the text).

MMHg, monomethyl mercury, methylmercury, and monomethylmercury (CH₃Hg⁺)

ng/g, nanogram per gram, equivalent to one (1) part per trillion.

ng/L, nanogram per liter, approximately equivalent to one (1) part per trillion.

ppm, parts per million, equivalent to mg/kg or µg/g.

SC, specific (electrical) conductivity, reported in units of millisiemens per centimeter (mS/cm).

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Introduction

Background and Objectives

The Contact and Sonoma mercury (Hg) deposits are among the youngest Hg deposits in the Coast Range Hg mineral belt and are located in the western part of the Clear Lake volcanic field in Sonoma County, California (fig. 1). The mine workings and tailings are located in the headwaters of Anna Belcher Creek, which is a tributary to Little Sulphur Creek. The Contact Hg mine produced about 1,000 flasks of Hg, and the Sonoma mine produced considerably less. Waste rock and tailings eroded from the Contact and Sonoma mines have contributed Hg-enriched mine waste material to the headwaters of Anna Belcher Creek. The mines are located on federal land managed by the U.S. Bureau of Land Management (USBLM). The USBLM requested that the U.S. Geological Survey (USGS) measure and characterize Hg and other geochemical constituents in tailings, sediment, water, and biota at the Contact and Sonoma mines and in Anna Belcher and Little Sulphur Creeks (fig. 2). This report is made in response to the USBLM request, the lead agency mandated to conduct a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Removal Site Investigation (RSI). The RSI applies to removal of Hg-contaminated mine waste from the Contact and Sonoma mines as a means of reducing Hg transport to Anna Belcher and Little Sulphur Creeks.

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This report summarizes data obtained from field sampling of mine tailings, waste rock, sediment, and water at the Contact and Sonoma mines that was initiated on April 20 during a storm event, and on June 19, 2001. Further sampling of water, sediment, and biota in a pond and tributaries that drain from the mine area was completed on April 1, 2003. Our results permit a preliminary assessment of the mining sources of Hg and associated chemical constituents that could elevate levels of monomethyl Hg (MMeHg) in tributaries and biota that are impacted by historic mining.

Mining History and Geology

The history of the Contact and Sonoma mines and the Anna Belcher prospect, summarized below, is from the U.S. Bureau of Mines (1965).

Contact Mine

Mercury ores were discovered in the area of the Contact Mine in the early 1870s, but the initial production was relatively small. Early mining utilized a Luckhart furnace to process from 10 to 15 tons per day of “adobe” ore that contained less than 1 per cent Hg (Egleston, 1890). The adobe consisted of soil mixed with water that was packed into moulds 7.5-cm wide by 10-cm long and high. The adobe bricks were dried prior to being placed in a furnace. The furnace consisted of a cast iron firebox positioned about 1.2 m above the bottom of a shaft. Ore was fed into the inclined firebox and heated to drive off the Hg that was released from the other side of the firebox after it had sufficiently cooled to be safely discharged. The amount of Hg produced from the early phase of mining is not known. Most of the 1,000 flasks of Hg produced from the mine occurred during operations that resumed in 1941.

At the Contact Mine, workings consisted of two adits, an inclined winze, a drainage tunnel, and an inclined shaft that provided access to several levels. These workings have caved in and flooded, except for the drainage tunnel that continues to release mine drainage. The underground workings explored a north-dipping sheared contact, between serpentine and sandstone, containing local bodies of silica-carbonate rock. Exploration of the contact continued for about 150 m along the strike and 90 m below the surface outcrop. The ore contains both cinnabar and native Hg in considerable quantity. The silica-carbonate ore contains cinnabar, whereas the sandstone ore contains disseminated native Hg in vugs of carbonate veins and well-formed cinnabar crystals, indicating that the native Hg did not form in place from alteration of cinnabar. Ore is also found locally in serpentine. Along the contact, a 2-10 cm wide vein of pure cinnabar was found. Ore was mined from two main stopes, the “east stope” and the “west stope.” The east stope extends for 45 m along a 45-degree slope from the east drift. The silica-carbonate ore of the east stope is localized by a sharp roll in the footwall of the fault. The west stope ore varies in type from silica-carbonate near the surface of the deep winze to native Hg found in sandstone at greater depths. Sediment and soils derived from the serpentinite contained primarily elemental Hg and minor cinnabar.

Sonoma Mine

The Sonoma Group is a group of seven claims located in 1873 when a small amount of Hg was produced. Workings explored a northwest-trending silica-carbonate ledge and the bordering sandstone. Cinnabar and native Hg were found in moderate quantities. Workings included nine crosscut adits and drifts on five levels that once extended for about 320 m. The underground workings are currently inaccessible due to caving. The remains of a washing plant and a retort are present at the mine site. The production from the mine is presumed to have been small but the considerable amount of calcines present suggests that at least several hundred flasks of Hg were produced.

Anna Belcher Prospect

A narrow mass of silicified serpentine was explored in the late 19th century, but no ore was found. Workings, including a 120-m adit, have caved in. There is no reported production for this prospect. The remains of an in-ground flume are present above the mine area.

Sample Locations and Methods

Sample Locations and Conditions

Samples were collected to assess the concentration of Hg and biogeochemically relevant constituents in tailings and waste-rock piles at the Contact and Sonoma mines (figs. 2, 3, and 4). Water, sediment, and biota were sampled from a pond located below the Contact Mine and just above the Sonoma mine (figs. 2, 4, 5, 6, and 7), from the upper most part of Anna Belcher Creek that originates in the Contact Mine tailings (figs. 2 and 8), and from the lower reach of the creek above its confluence with Little Sulphur Creek (figs. 5, 9, 10, and 11). Water and sediment samples were collected from Little Sulphur Creek at three sites to evaluate the relative importance of the contribution of Hg-enriched sediment from Anna Belcher Creek. Sample-site locations are shown in figures 2, 5, and 9 and listed in tables 1, 2 and 3. The April 20, 2001, sampling occurred during a storm that resulted in higher stream flow and significant surface runoff. Sampling on April 1, 2003, occurred when stream flow was low, and there was no precipitation.

Field Sampling Methods

Dry Sediments and Tailings

Samples consisting of 100 to 500 g of mine tailings and waste rock were collected from waste-rock and tailings piles at the Contact and Sonoma mines. Sediment samples from the pond and creeks were placed in 125 mL jars. Tailings and waste-rock samples were stored and shipped in Ziploc[®] bags at ambient temperature. Wet sediment for total Hg (Hg_T) and MMeHg analysis were stored on ice within approximately one hour after collection, kept frozen in the laboratory until shipped overnight on dry ice to analytical laboratories where they were kept frozen until analysis. The temperature of samples arriving at the analytical facilities ranged from 1 to 4°C, which is within the limits specified in USEPA Method 1631E.

A representative sample of tailings from the Contact Mine and another from the Sonoma Mine were dry sieved using steel wire-mesh screens to obtain eleven size fractions for each sample ranging in size from >2830 µm to < 20 µm. All dry tailings subsamples were placed in pre-cleaned and certified borosilicate glass jars with TeflonTM seals (I-CHEMTM Series 300).

Wet Sediments and Tailings

Wet sediments and tailings samples were collected in Certified TeflonTM-sealed I-CHEMTM glass jars (the same as were used for dry sediments). Polycarbonate jars (100 ml capacity) were used for Hg subsamples. These samples were frozen with dry ice immediately after collection (freezing time approximately 20-30 minutes) and kept frozen until analysis.

Water

Stream and pond samples were collected with new 60-mL sterile polypropylene syringes. Bulk water samples were subsampled for analysis of metal(loid)s and anions. Subsamples for metal(loid)s determinations were acidified to pH<2 with trace metal (*Ultrex*, J.T. Baker)-grade HNO₃ and stored in

acid-washed, high-density polyethylene (HDPE) bottles. Subsamples for anion and alkalinity measurements were filtered, stored in HDPE bottles, and chilled to approximately 4°C until analysis, in accordance with USGS protocols for trace metals (<http://water.usgs.gov/owq/FieldManual/>). Water samples were filtered with disposable 25 mm-diameter sterile cellulose acetate filters (0.45 µm openings) in the field for analysis of anions, alkalinity, and inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectrometry (ICP-AES) analysis.

Water variables, including pH, conductivity, and temperature, were measured in the field using a battery-powered pH meter (Orion Model 290, with low-maintenance sealed gel triode electrode) and a specific-conductivity meter (Orion Model 120). The pH triode, which has automatic temperature compensation, was also used for temperature measurements. Measurements were taken by placing the probe directly into the flowing stream or pond water.

Samples for Hg_T and MMeHg analyses were collected in trace metal-free-certified 1-L borosilicate bottles (Nalgene ICHM) with no headspace and Teflon-lined caps. Sampling for Hg_T analysis followed ultra-clean sampling and handling protocols (Bloom, 1995, Gill and Fitzgerald, 1987) during the collection of field samples and analysis to avoid introduction of Hg. Samples were kept on ice until shipped. Samples were shipped on dry ice or blue ice packs and arrived the next morning at the analytical facilities at temperatures ranging from 1 to 4° C, which is specified by EPA Method 1631E to minimize biologically induced phase changes and MMeHg degradation.

During every sampling event, a field blank was collected by processing de-ionized water and collecting the same subsamples (except for alkalinity) following the same procedures as used for the field samples. Laboratory blanks and acid blanks were processed periodically to determine whether our equipment, containers, reagents, and procedures introduced significant contamination.

Invertebrates

The target macroinvertebrates for this study were predatory insects, depending on their abundance and availability at each sample site. Taxa collected were larval dragonflies (order Odonata, family Gomphidae, Aeshnidae, and Cordulegastridae), adults of two families of the order Hemiptera (water striders, family Gerridae; and water boatmen, family Corixidae), larval stoneflies (order Plecoptera, family Perlidae), and larval Dobsonflies (order Megaloptera, family Corydalidae; table 4).

Invertebrates were collected using dip nets and by hand (figs. 7 and 10) and placed in Ziploc[®] plastic bags with native water. Samples were kept in a cooler and allowed to depurate in native water on wet ice for 4-24 hours before they were sorted at the end of each collection day. Individuals were sorted by family and placed in disposable dishes using Teflon-coated forceps or by hand while wearing disposable latex gloves. When possible, we collected replicate samples, multiple size classes within a taxon, or both in order to assess variability in concentration and identify any relationships of tissue concentrations with size. Organisms were rinsed clean with deionized water and patted dry with a clean paper towel. Then samples were sorted, and composited by family with the goal of obtaining a minimum of one gram wet biomass. Each sample consisted of 1-25 individuals of the same family (0.49-1.91 g total mass). Samples were weighed on an electronic balance, placed into chemically cleaned glass jars with Teflon-lined lids. The lids were sealed with Parafilm[®], and the samples were frozen until they could be shipped to the laboratory for Hg_T analysis and, where mass was sufficient, MMeHg and percent moisture.

Fish

We collected rainbow trout (*Oncorhynchus mykiss*) at two Anna Belcher sites in April 2003, Anna Belcher at Twin Falls (ABTF; fig. 10), and Anna Belcher above Little Sulfur Creek (ABUS; fig. 11 and table 5). Similar sizes and species were collected, as far as possible, by using a backpack electroshocker. Captured fish were held in native water in buckets. Each fish was weighed and measured for standard and

total length, individually wrapped in aluminum foil, placed in polyethylene Ziploc® bags, and asphyxiated in a cooler. Samples were frozen until they could be processed. Each fish was examined for gross deformities and dissected to determine sex. The gastrointestinal (GI) tract of each fish was removed, and the stomach contents were preserved for later identification. Whole body samples were processed according to procedures described by May and others (2000). Samples were placed in individual, chemically cleaned glass sample jars with Teflon-lined lids and frozen for no more than 30 days before being sent to the laboratory for analysis.

Analytical Methods

Sediments and Tailings

Multi-element analyses for all dry sediments and tailings were performed in the laboratories of ALS Chemex. Bulk samples were ground in a zirconia ring mill and subjected to a near-total four-acid digestion. Major elements were determined by ICP-AES. Minor elements, other than Hg, were determined by ICP-MS. Mercury was determined by cold vapor atomic absorption spectroscopy (CVAAS) following methods similar to those described by Crock (1996) and O'Leary and others (1996).

Mercury and MMeHg analyses for all wet sediments were done at Frontier Geosciences. Some dry sediments analyzed by Chemex were also analyzed by Frontier. For total mercury, the sediment was leached with cold aqua regia, followed by stannous chloride (SnCl_2) reduction, two-stage gold amalgamation, and cold vapor atomic fluorescence spectroscopy (CVAFS) detection.

Monomethylmercury was obtained by acid bromide/methyl chloride extraction followed by aqueous phase ethylation, isothermal gas chromatographic (GC) separation, and CVAFS detection (Horvat and others, 1993). Results were reported on both a wet- and dry-weight basis.

Waters

Alkalinity as CaCO_3 was determined in the laboratory by titration with H_2SO_4 , using Gran's technique (Orion Research, Inc., 1978), within 2-4 days after sample collection. Sulfate, chloride, nitrate, and fluoride concentrations were determined by ion chromatography (Fishman and Pyen, 1979).

Cations were analyzed by ICP-AES and ICP-MS. Ion chromatography and alkalinity analyses were performed in USGS laboratories under the direction of Paul Lamothe. The ICP-AES analyses were determined in USGS laboratories under the direction of Paul Briggs. Duplicate water samples, blank samples, and USGS Water Resource Division standard reference waters were analyzed with the data set.

At Frontier Geosciences, samples were handled in a Class-100 clean air station that was monitored routinely for low levels of total gaseous Hg. An ultra-clean Hg trace-metal protocol was followed, including the use of rigorously cleaned and tested Teflon™ equipment and sample bottles and pre-screened and purified reagents. Laboratory atmosphere and water supply were also routinely monitored for low levels of Hg. Primary standards used in the laboratory were NIST-certified, or traceable to NIST-certified materials. Following USEPA Method 1631, MMeHg standards were made from pure powder and calibrated against NBS-3133; they were cross-verified by daily analysis of Certified Reference Material DORM-2 (National Research Council of Canada Institute for National Measurement Standards, 1999). Total Hg was determined by bromine monochloride (BrCl) oxidation followed by SnCl_2 reduction, two-stage gold amalgamation, and detection by CVAFS (Bloom and others, 1988). Monomethylmercury was liberated from water using an all-Teflon™ distillation system. Distilled samples were analyzed using aqueous phase ethylation with purging onto Carbotrap, isothermal GC separation, and CVAFS detection (Bloom, 1989). To address accuracy and precision, quality-assurance measures were employed with the following minimum frequency: laboratory duplicates, one per ten samples; method blanks, three per

analytical batch; filtration blanks, one per ten samples; and spike recovery or standard reference material, one per ten samples.

Biota

Invertebrate samples were analyzed for both Hg_T and $MMeHg$, while fish samples were analyzed only for Hg_T . Samples were received frozen within 30 days of collection at Frontier Geosciences, Inc. were assigned unique identification numbers. The samples were placed in frozen storage until sample preparation could take place. Monomethyl Hg in tissue was prepared by a 25% KOH in methanol digestion and analyzed by aqueous phase ethylation, isothermal GC separation, and CVAFS detection (Frontier SOP's FGS-010, FGS-070). Total Hg in tissue was prepared by a 70/30 nitric/sulfuric digestion and analyzed by $SnCl_2$ reduction, dual gold amalgamation, and CVAFS detection (Frontier SOP's FGS-011, FGS-069). All results are reported on both a wet and dry weight basis.

Quality Assurance/Quality Control for Biota

All standard environmental laboratory and field Quality Assurance/Quality Control (QA/QC) procedures were followed for this study. Calibration of all instruments utilized a blank and at least three calibration standards that bracketed the measured sample concentrations. Instrument response was evaluated by running a check standard and a check blank immediately following calibration and, thereafter, following every 10 samples and at the end of the analytical run. Laboratory quality-control samples went through both digestion and analytical steps, and included method blanks, certified reference materials, duplicate samples, and spiked samples with each analytical batch of 20 or fewer samples. Analyses of blanks, duplicates, spiked samples, and Standard Reference Materials were performed, and all results were acceptable.

Results

Tailings at the Contact and Sonoma Mine Areas

The concentration of Hg in waste materials at the Contact and Sonoma mine areas varies depending on material type. Ores at the Contact Mine were primarily processed in a rotary furnace, and calcines (tailings) were deposited on a steep slope below the furnace and condenser facility (fig. 3). At the Sonoma Mine, a rotary furnace was used, but a presumably small amount of ore was processed in a brick retort; a small amount of calcines are present near the remains of the retort and in a drainage that connects the mine area to Anna Belcher Creek. The calcines at the Contact Mine vary from coarse pebble to fine sand-size calcines that are well bedded. The calcines are variably cemented by magnesite and individual larger particles in the calcines are variably coated with a white material that is largely composed of magnesite. There is little vegetation on the calcines and only the cementation of the calcines by magnesite helps to mitigate erosion. Since mining has ceased, a considerable amount of calcines has eroded from the pile (see figs. 3 and 4 for comparison). The Contact Mine calcines contain relatively low concentrations of Hg, typically ranging from 3.7 to 65 ppm, with only one sample exceeding that range and containing 200 ppm (table 3). One sample of low-grade ore (sample 21-CT-OR; table 3) on the waste-rock pile had visible cinnabar in carbonate veins and contained 17,000 ppm Hg. A sample of calcines (21CT50) from the Contact Mine was dry sieved to 11 size fractions, and each fraction was analyzed for major and minor elements. The Hg concentration in the calcines increases with decreasing particle size (appendix A). The concentration in the largest grain-size fraction, $>2,830\ \mu m$, is 8.3 ppm; in the finest grain-size fraction, $<20\ \mu m$, concentration is 28.8 ppm, an increase of 350%. Other elements of potential environmental concern that increase with decreasing grain size and have relatively high concentrations include Cu (160 ppm) and Zn (100 ppm; appendix A).

The Sonoma Mine calcines are located on a moderately steep slope that is highly vegetated. The location mitigates erosion of the calcines. Unlike the calcines at the Contact Mine, the Sonoma Mine calcines are not cemented by magnesite and consist of coarse pebble- to silt-size beds of calcines. Some of the calcines contain a significant amount of very fine-grained material. The Hg concentration in the Sonoma Mine calcines ranges from 14.8 to 91.4 ppm (table 3). Calcines from the Contact and Sonoma mines have elevated concentrations of Co, Cr, and Ni that reflect the serpentinite host rock. Exceptionally high levels of Mg, 14-15 % are present in the Contact Mine calcines as a result of the large amount of magnesite that coats and cements the calcines. Unusually high concentrations of tellurium, up to 2.8 ppm, are present in the calcines. Typically, tellurium is present at concentrations < 0.05 ppm, so the detection of tellurium at levels greater than 1 ppm is significant. Tellurium is enriched in hydrothermal ore deposits that have a magmatic contribution. The presence of intrusive rocks nearby at The Geysers may be a potential source. No other trace elements are present in high concentrations except for one sample from the Sonoma calcines that contains 340 ppm Hg (table 3, sample 21 SCT-5C). Gold was detected in three samples from the Sonoma calcines, up to 210 ppb. Trace metals that are moderately elevated and exceed the USBLM Ecotoxicity screening criteria include As (4 ppm), Cu (7 ppm), Pb (6 ppm), and Zn (43 ppm; table 3). However, these elements do not exceed the USBLM Camper screening criteria or the USEPA preliminary remediation goals (PRGs).

A sample of calcines from the Sonoma Mine (21CT8C) was dry sieved to 11 size fractions, and each fraction analyzed for major and minor elements. The Hg concentration in the calcines is highest (66.4 ppm) in the largest grain-size fraction, >2830 μm . In the next largest grain-size fraction, 2,830-1,700 μm , Hg decreases to 12.8 ppm and then linearly increases to 31.8 ppm in the < 20 μm grain-size fraction (appendix B). Because of the high concentration and abundant mass of material in the coarsest grain-size fraction, 55% of the Hg is in the >2,830 μm fraction. Other elements of potential environmental concern that increase with decreasing grain size and have relatively high concentrations include As (12 ppm), Co (250 ppm), Fe (14,000 ppm), Ni (4,500 ppm) and Zn (140 ppm).

Sediment at and below the Contact and Sonoma Mines

The headwaters of Anna Belcher Creek begin above the Contact Mine calcine pile and cut through the north side of the calcines. Sediment in the creek below the calcines has an elevated Hg concentration, 14 ppm (table 3, sample 23CT2S). Sediment from sample sites in Anna Belcher Creek taken downstream from the Contact and Sonoma mines has elevated concentrations of Hg ranging from 4.7 to >100 ppm. The Hg concentration in the sediment is highly variable. At the sample site just above the confluence with Little Sulphur Creek (23AB2S, table 3 and fig. 9) the Hg concentration in two samples was 4.7 and >100 ppm. Sediment in Little Sulphur Creek above the confluence with Anna Belcher Creek has a relatively low Hg concentration, 0.43 ppm, as compared to sediment below the confluence, which has elevated Hg concentration, 9.67 ppm (22LS3, table 3). The higher Hg concentration below the confluence demonstrates that significant Hg enriched sediment is being released into Little Sulphur Creek from Anna Belcher Creek. At sample site 22LS1, about 2 km downstream from the confluence, the Hg concentrations in Little Sulphur Creek are also elevated, 1.4 to 2.9 ppm (table 3).

Monomethylmercury concentrations in sediment samples vary considerably ranging from 0.43 ng/g to 14.2 ng/g (table 6). The highest MMeHg concentration occurs in sediment from the pond located above the Sonoma Mine, and relatively low concentrations occur in sediment from the upper part of Anna Belcher Creek located adjacent to the Contact and Sonoma mine areas. Elevated MMeHg and Hg concentrations are present in Anna Belcher Creek sediment (sample site 23AB2) just above the confluence with Little Sulphur Creek, as compared to concentrations in Little Sulphur Creek above the confluence (tables 3 and 6). The %MMeHg in sediments (table 6 and fig. 12) can be used as an indicator for net production of MMeHg when the concentration of MMeHg is normalized to Hg_T (Drott and others, 2008). The %MMeHg is derived by dividing the measured concentrations of MMeHg in sediment by the total Hg

concentration present in the same sample: $\% \text{MMeHg} = (\text{MMeHg in ng/g in sediment})/(\text{Hg}_T \text{ in ng/g in sediment})$.

Sediment from the pond above the Sonoma Mine has the highest %MMeHg when compared to sediment from Anna Belcher and Little Sulphur Creek. This high value indicates that the high amount of dissolved organic matter (DOM) present in the very shallow surface and pore waters of the pond make the pond environment highly favorable for the production of MMeHg. The relatively low levels of % MMeHg in stream sediments in Anna Belcher and Little Sulphur Creeks likely reflect low levels of DOM that limit production of MMeHg even though Hg_T levels in the sediment are elevated.

Water Chemistry

All the waters in the mine area and in Anna Belcher Creek are alkaline to nearly neutral as a result of the serpentinite that underlies most of the watershed and the presence of carbonate alteration in the mine area (table 1). The sulfate concentration in all mine, pond and stream waters is anomalous ranging from 6.3 to 20 ppm (table 7). The highest sulfate concentrations occur in mine drainage from the adit at the Contact Mine. High concentrations of Mg and carbonate are present in all waters with the highest concentrations associated with mine drainage and surface waters in the Contact Mine area (tables 7-9).

Hg and MMeHg in waters

Concentrations of Hg_T and MMeHg in waters sampled at and downstream from the Contact and Sonoma mine areas are highly variable and dependent on flow conditions. Under high-flow conditions present during the storm-event sampling in April 2001, both Hg_T and MMeHg concentrations in waters were moderately to highly elevated, ranging from 104 to 13,900 ng/L for unfiltered Hg and 0.046 to 17 ng/L for unfiltered MMeHg (table 6). The highest concentrations of Hg_T and MMeHg measured occur in waters in a side tributary to Anna Belcher Creek that receives runoff from the Sonoma mine area. This tributary contains calcines and brick fragments from a brick retort in the active channel and in bank sediments that are mobilized during high-flow events. Water samples from the uppermost part of Anna Belcher Creek adjacent to the Contact Mine calcines have moderately elevated levels of Hg and MMeHg (21CT2), as do water samples from the Contact Mine drainage tunnel (21CT1). During high-flow events, most of the Hg_T is transported as particulates, as indicated by the plot of Hg total versus Hg filtered ($0.45\mu\text{m}$; fig. 13), which shows that dissolved Hg is less than 15% of the Hg present. Under low-flow conditions during the 2003 sampling event, concentrations of Hg_T and MMeHg were all considerably lower than they were in storm-event samples. For comparison, water samples from the upper part of Anna Belcher Creek, just below the Contact Mine calcines, had a total Hg concentration of 40 ng/L, as compared to 104 ng/L for storm-event samples; and the MMeHg concentration was below the detection limit of 0.025 ng/L, as compared to 0.046 ng/L for samples collected during the storm event.

The Hg_T concentrations in water samples collected from Anna Belcher and Little Sulfur Creeks, below the mine areas, were relatively low, ranging from 2.45 to 13.7 ng/L; this is below the 50 ng/L standard and near or below the water-quality objective of 12 ng/L (fig. 13, table 6). Under low-flow conditions, most of the Hg_T is present in the dissolved fraction (filtered fraction; fig. 13). The highest concentration of MMeHg occurs in pond water samples where MMeHg comprises more than 20% of the total Hg (fig. 14). Monomethyl Hg concentration in Anna Belcher and Little Sulphur Creek water samples is relatively low and comprises less than 0.1% of the total Hg in the waters.

Invertebrates

We collected 34 samples of aquatic invertebrates from four sites in the Anna Belcher Creek watershed and analyzed them for Hg_T and MMeHg. We compared MMeHg concentrations in

invertebrates collected from the watershed in 2003 with the same or similar taxa collected from the BR20 reference site during 1999-2002 (table 4).

The reference samples from BR20 had Hg_T concentrations ranging from 0.022 to 0.076 $\mu g/g$, and MMeHg concentrations ranging between 0.014 and 0.068 $\mu g/g$ (all values are reported on a wet-weight basis). The Hg_T and MMeHg concentrations in samples collected from the Anna Belcher watershed were more variable, ranging from 0.092 to 0.660 $\mu g/g$ MMeHg and 0.131 to 0.692 $\mu g/g$ Hg_T . The geometric means of MMeHg in taxa from the reference site (BR20) were all exceeded by the geometric means of the same or similar taxa from the Anna Belcher sites.

The highest values were found in Corixidae (water boatmen, order Hemiptera) from the Sonoma Mine Pond, (SOPD) with a geometric mean of 0.573 $\mu g/g$, 16 times higher than the mean value (0.035 $\mu g/g$) found in Gerridae from a reference site (BR20). Geometric mean Gerridae values from all the sites in this study, ranging from 0.116 $\mu g/g$ to 0.243 $\mu g/g$, also greatly exceeded those of Gerridae from the reference site (fig. 15).

All MMeHg concentrations in dragonfly larvae (Aeshnidae, Libellulidae, and Cordulegastridae) samples were much higher than those in Aeshnidae samples from the reference site. The highest concentration (0.247 $\mu g/g$) in Cordulegastridae samples from Anna Belcher at Twin Falls (ABTF; fig. 10) was 13 times higher than the geometric mean concentration for the reference (0.019 $\mu g/g$; fig. 16).

The Perlidae (stoneflies) and the Corydalidae (Dobsonflies) samples (fig. 17) also had mean MMeHg concentrations that were higher than those from the reference site, the most similar values being from stonefly samples from Anna Belcher Twin Falls (0.156 $\mu g/g$), which were three times higher than the reference values (0.052 $\mu g/g$).

Fish

Samples of rainbow trout were collected from two sites in Anna Belcher Creek in April 2003. No statistical difference was noted between fish from the two Anna Belcher sites (ABTF and ABUS; $P=0.738$, $F=0.120$, One-Way ANOVA). These values were compared to values from brown trout collected in 1999 from a reference site (BR20; table 5). Rainbow trout from Anna Belcher had statistically higher geometric means than did fillets of brown trout (table 5; $P<0.001$, $F=33.525$, One-Way ANOVA; fig. 18).

Conclusions

Calcines and waste rock eroded from the Contact and Sonoma mines have contributed Hg-enriched sediment to Anna Belcher and Little Sulphur Creeks. A significant amount of calcines still remains at the Contact Mine, and natural cementation of calcines by magnesite only partially mitigates erosion of the calcines. The calcines have very high Mg concentration, 14-15 % because of the magnesite cement, but relatively low Hg concentrations, 3.7 to 65 ppm, (one sample with 200 ppm Hg exceeded the range). Mercury concentration in the calcines increases with decreasing grain size, resulting in about 350% higher Hg concentration in the finest grain-size fraction ($<20 \mu m$) as compared to the largest grain-size fraction (2,830 μm). Unusually high concentrations of tellurium, up to 2.8 ppm, are present in the calcines. The Sonoma Mine calcines are not cemented, but are covered by vegetation that serves to limit erosion and the release of Hg-enriched sediment. The Hg concentrations in the Sonoma Mine calcines are relatively low (14.8-91.4 ppm). Mercury concentration increases with decreasing grain size, but the highest Hg concentration occurs in the coarsest grain-size fraction, indicating that HgS remains encapsulated in the larger fragments. Calcines from both mines have elevated concentrations of Co, Cr, and Ni that reflect the serpentinite host rock.

Concentrations of Hg_T and MMeHg in waters sampled at and downstream from the Contact and Sonoma mine areas are dependent on flow conditions. Highest concentrations occur under high-flow conditions (104-13,900 ng/L for Hg_T , and 0.046-17 ng/L for unfiltered MMeHg). The highest

concentrations of Hg_T and MMeHg occurred in waters in a side tributary to Anna Belcher Creek that receives runoff from the Sonoma mine area. Below the mine area, Hg_T concentrations in water samples from Anna Belcher and Little Sulphur Creeks were relatively low, meet the 50 ng/L USEPA criterion (USEPA, 1999), and are near or below the water-quality objective of 12 ng/L. The highest concentration of MMeHg occurs in pond water samples from above the Sonoma Mine workings. MMeHg concentration in samples from Anna Belcher and Little Sulphur Creek is relatively low. Methylation of mercury is highest in the pond, as indicated by the %MMeHg in sediment, and relatively low in the lower reach of Anna Belcher Creek.

Anna Belcher Creek flows through the north side of the Contact Mine calcine pile and, during storm events, Hg-enriched sediment is released into the creek. This release of Hg-enriched sediment results in variable but always-elevated concentrations of Hg (4.7 to >100 ppm) in the bed-load sediment downstream from the mine area. Hg-enriched sediment from Anna Belcher Creek increases the Hg concentration of sediment in Little Sulphur Creek for at least 2 km downstream from the confluence.

The highest concentration of MMeHg in the invertebrate samples was in water boatmen (Corixidae) samples from the Sonoma Mine pond. The MMeHg concentration was 16 times higher than mean values found in a comparable taxon, water striders (Gerridae), from a reference site. The data for biota from the Sonoma pond are consistent with the high percentage of MMeHg found in the pond sediment, which indicates a high level of MMeHg production in the pond environment. In Anna Belcher Creek downstream from the mine area, MMeHg concentrations in dragonfly larvae (Aeshnidae, Libellulidae, and Cordulegastridae) samples were much higher than those in Aeshnidae samples from the reference site. The highest value recorded for the Cordulegastridae samples from the creek at the Twin Falls site was 13 times higher than the reference value. No statistical difference was noted between rainbow trout samples from the two Anna Belcher sites, but the concentrations from both sites were statistically higher than those in brown trout from a reference site. The biota data indicate that the Hg-enriched sediment released from the Contact and Sonoma mines and then methylated in both pond and stream environments is bioaccumulated in both invertebrates and fish.

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Table 1. Sample locations (NAD 27) and physical and selected chemical parameters for water samples from the Contact and Sonoma mine areas and Anna Belcher and Little Sulphur Creeks, Sonoma County, California.

Field number	Latitude	Longitude	Sampling date	Sample-site description	Conductivity micro Siemens	pH	Temperature °C
Contact Mine							
21CT1	38.757531	-122.764196	4/20/2001	Contact Sonoma Drainage Adit 1.5 L/minute	460	7.50	17.5
21CT2	38.757819	-122.764844	4/20/2001	Creek beyond lowest tailings (calcines 21CT6 and 7C)	314	8.45	8.5
21CT3	38.752774	-122.767522	4/20/2001	Creek below retort remains and pond area	499	8.17	8.28
21CT4	38.752624	-122.768805	4/20/2001	Adit along road	731	8.28	10.6
23CT1C	38.75365	-122.76726	4/1/2003	Contact Mine Pond	44.1	6.83	13.4
23CT2C	38.75786	-122.76490	4/1/2003	Contact Mine Stream 8 gal/minute	61.3	8.44	11.5
Anna Belcher Creek							
23AB1C	38.74722	-122.76362	4/1/2003	Anna Belcher creek at pond below water fall	59.8	8.00	13.5
23AB2C	38.74195	-122.76964	4/1/2003	Anna Belcher creek downstream from AB1	57.3	7.73	14.2
Little Sulphur Creek							
22LS1C	38.76833	-122.82044	4/20/2001	Little Sulphur Creek	287	7.01	15.6

Table 2. Collection sites, NAD 27, for biological samples in the Anna Belcher Creek watershed, 2003, and at a reference site, Bear River at Highway 20, Sonoma County, California.

Site Code	Site description	Watershed	County	Sampling date(s)	Latitude	Longitude
ABUS	Anna Belcher above Little Sulfur Cr.	Russian River	Sonoma	4/1/2003	38° 44' 31.0"	122° 46' 10.7"
ABTF	Anna Belcher at Twin Falls	Russian River	Sonoma	4/1/2003	38° 44' 47.7"	122° 45' 53.5"
ABCM	Contact Mine	Russian River	Sonoma	4/1/2003	38° 45' 27.9"	122° 45' 53.5"
SOPD	Sonoma Mine Pond	Russian River	Sonoma	4/1/2003	38° 45' 13.1"	122° 46' 02.1"
BR20	Bear River at HWY 20	Bear River	Nevada/Placer	1999-2002	39° 18' 23"	120° 40' 41"

Table 3. Mercury and associated major and minor elements in sediment, precipitates, and calcine samples from Contact and Sonoma Mines and Anna Belcher and Little Sulphur Creek watersheds, Sonoma County, California.

Field number	Latitude	Longitude	Sampling date	Sample site description	Hg ppm	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm
Contact Mine Area Sediment											
21CT 2S	38.75782	-122.764844	4/20/2001	Sand in Anna Belcher Ck (below calcines 21CT6)	34.2	0.32	5.53	7.4	371.5	0.95	0.11
23CT 1S	38.75365	-122.76726	4/1/2003	Contact Mine Pond	3.17	0.10	7.10	7.7	620	1.18	0.14
23CT 2S	38.75786	-122.76490	4/1/2003	Contact Mine Stream 8 gal/minute	14.1	0.07	6.26	8.5	460	0.94	0.12
Contact Mine Ore and Calcines											
21 - CT - OR	38.75861	-122.76349		Waste rock dump with low carbonate -HgS veins	17000	0.06	0.33	1.6	91.5	0.05	<0.01
21 - CT - C1	38.75822	-122.76433	4/20/2001	Well bedded magnesite cemented middle calcine	200	0.12	1.02	3.8	185	0.1	0.01
21 - CT - C2	38.75837	-122.76399	4/20/2001	Upper most calcine along stone wall	65.1	0.06	0.75	2.0	139	<0.1	<0.01
21 - CT - C3	38.75822	-122.76433	4/20/2001	Middle pile channel sample	14.5	0.16	2.64	4.4	226	0.35	0.03
21 - CT - C4	38.75815	-122.76453	4/20/2001	Cemented calcines in creek above C5	16.2	0.12	0.91	1.4	159	0.25	0.01
21 - CT - C5	38.758	-122.7647	4/20/2001	Lowest calcine at stream cut on waste rock	19.3	0.10	1.13	<0.2	164.5	0.25	0.01
21 - CT - 6C	38.75856	-122.76442	4/20/2001	Lowest calcine above C4	3.73	0.20	3.00	3.8	346	0.55	0.05
21 - CT - C7	38.75859	-122.76448	4/20/2001	Lowest calcine above C4	5.78	0.34	5.83	8.0	507.3	0.75	0.08
21 - CT - C8	38.75797	-122.76483	4/20/2001	Calcine in creek	23.9	0.78	4.29	8.2	304	1.05	0.10
21 -CT401C1	38.75828	-122.76439	4/20/2001	Middle upper calcine pile	26.2	0.08	1.55	4.2	184	0.45	0.01
CT0404C2	38.75828	-122.76439	4/20/2001	Channel 0.5 m cemented fine and coarse	8.35	0.16	0.83	0.8	187.5	0.15	<0.01
21 CT 50	38.75837	-122.76399	4/20/2001	Contact Mine selected fines from calcine	11.8	0.02	3.50	5.0	302.5	0.60	0.19
Sonoma Mine Calcines and Sediment											
21 SCT-3C	38.75277	-122.767522	6/19/2001	Coarse calcine and bricks in Creek by retort	14.8	0.04	4.40	9.2	295.5	0.70	2.25
21 CT 3S	38.75277	-122.767522	6/19/2001	Sediment in creek below retort at site 21 SCT-3C	91.4	0.10	5.68	9.4	301	0.95	0.18
21 SCT-5C	38.75321	-122.767420	6/19/2001	Calcine and ash from 2 pipe retort at concrete pad	17.1	<0.1	2.99	5.2	2620	0.20	1.10
21 SCT-6C	38.75267	-122.766670	6/19/2001	Red fine grained calcine 300' downstream SCT-3	66.4	0.10	3.44	7.2	259	0.55	1.03
21 SCT-7C	38.75267	-122.766390	6/19/2001	Red fine grained calcine 40' south of SCT-6c	59.9	0.04	4.39	7.6	305	0.65	0.58
21 SCT-8C	38.75296	-122.766670	6/19/2001	Red fine grained calcine 40' upslope from SCT-6c	22.8	0.10	3.97	7.0	279	0.75	0.60
Anna Belcher Creek											
22 AB1	38.74615	-122.764	7/31/2002	Anna Belcher creek downstream	50.0	0.02	6.40	8.6	1144	1.15	0.13
22 AB2	38.74195	-122.76964	7/31/2002	Downstream from AB1	12.1	0.02	5.83	7.0	594.3	1.10	0.11
23AB 1S	38.74722	-122.76362	4/1/2003	At pond below waterfall	5.57	0.29	5.90	10.1	560	0.97	0.20
23AB 2SA	38.74195	-122.76964	4/1/2003	Downstream from 23 AB1	>100	0.12	6.28	8.8	990	1.08	0.14
23AB 2SB	38.74195	-122.76964	4/1/2003	Downstream from 23 AB1	4.76	0.06	5.65	7.9	430	0.99	0.12
Little Sulphur Creek											
22 LS 1SA	38.76833	-122.82044	4/20/2001	Little Sulphur Creek	1.47	0.02	6.35	6.8	702.8	1.10	0.10
22 LS 1SB	38.76452	-122.81106	4/20/2001	Little Sulphur Creek	2.94	<0.1	5.88	6.8	405	1.05	0.10
22 LS 2	38.74009	-122.76724	4/20/2001	Little Sulphur Creek	0.43	0.04	6.14	7.2	469	1.00	0.12
22 LS 3	38.74571	-122.78021	4/20/2001	Little Sulphur Creek	9.67	0.02	6.07	7.0	447	1.05	0.09

Table 3 (continued). Mercury and associated major and minor elements in sediment, precipitates, and calcine samples from Contact and Sonoma Mines and Anna Belcher and Little Sulphur Creek watersheds, Sonoma County, California.

Field number	Ca %	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cs ppm	Cu ppm	Fe %	Ga ppm	Ge ppm	Hf ppm	In ppm	K %	La ppm	Li ppm	Mg %	Mn ppm	Mo ppm	Na %
21CT 2S	1.05	0.12	24.3	29.8	475	2.00	40.0	3.90	10.85	0.25	1.3	0.055	1.06	13.0	29.0	4.42	585	0.60	1.03
23CT 1S	0.51	0.12	47.6	23.2	206	3.81	43.5	3.78	16.8	0.15	2.5	0.040	1.58	19.9	34.6	1.94	513	0.76	1.14
23CT 2S	1.02	0.12	32.5	36.2	496	2.51	40.5	4.57	13.9	0.16	1.9	0.036	1.38	13.9	36.3	5.06	820	0.74	0.96
21 - CT OR	0.59	<0.02	0.12	33.4	1020	0.20	8.6	2.25	0.70	0.30	<0.1	0.010	0.01	<0.5	11.2	11.35	405	0.25	0.01
21 - CT-C1	2.9	0.02	3.65	62.0	1175	0.45	15.0	3.56	2.2	0.25	<0.1	0.015	0.07	2.0	12.4	14.95	625	0.30	0.06
21 - CT-C2	1.00	<0.02	1.24	88.3	1610	0.25	14.0	4.15	1.65	0.25	<0.1	0.015	0.03	0.5	19.8	14.65	660	0.20	0.01
21 - CT-C3	0.71	0.02	10.75	69.2	1325	1.05	23.4	4.72	5.6	0.30	0.5	0.035	0.40	6.0	21.8	11.30	655	0.45	0.34
21 - CT-C4	1.60	0.02	2.67	87.8	1620	0.35	16.0	4.20	2.3	0.15	<0.1	0.010	0.06	1.5	18.2	14.70	650	0.40	0.04
21 - CT-C5	1.60	0.02	3.70	81.6	1380	0.45	16.4	4.16	2.5	0.30	<0.1	0.020	0.10	2.0	16.4	13.60	635	0.30	0.05
21 - CT-6C	1.55	0.08	13.45	67.9	1275	0.70	41.0	4.48	6.7	0.25	0.6	0.035	0.17	7.0	14.0	12.95	785	0.70	0.03
21 - CT-C7	1.30	0.10	26.20	28.9	438	1.85	41.0	3.72	13.3	0.35	1.5	0.045	1.03	15.5	20.2	4.06	615	0.65	0.84
21 - CT-C8	0.17	0.14	22.1	222.5	2490	2.30	43.2	9.47	10.1	0.65	0.7	0.040	0.46	11.0	30.0	1.19	1595	0.60	0.26
21CT0401C1	1.15	0.04	5.50	94.0	1710	0.55	22.8	4.87	3.7	0.40	0.2	0.020	0.17	3.0	17.4	14.95	730	0.35	0.11
CT0404C2	1.55	<0.02	2.36	79.8	1165	0.30	14.4	3.78	2.1	0.05	<0.1	0.015	0.07	1.5	13.8	>15.00	590	0.40	0.04
21 CT 50	2.00	0.08	22.1	54.9	811	1.30	30.2	4.58	8.6	0.10	1.0	0.030	0.50	10.5	14.4	9.68	755	0.70	0.17
21 SCT-3C	0.20	0.20	24.8	201.9	2810	2.20	40.2	10.25	9.85	0.20	0.8	0.030	0.53	11.0	26.6	1.17	1760	0.80	0.33
21 CT 3S	0.11	0.10	29.8	86.4	878	3.05	44.4	6.35	13.0	0.15	1.2	0.045	0.77	13.5	29.6	2.09	930	1.15	0.37
21 SCT-5C	5.20	0.18	20.9	88.4	>10000	0.40	39.0	9.71	7.75	0.35	0.6	0.025	0.32	10.0	10.4	2.26	1290	2.45	0.71
21 SCT-6C	0.19	0.08	19.05	166.8	3190	1.70	28.4	8.71	7.75	0.20	0.7	0.030	0.33	8.5	22.4	2.23	1360	0.75	0.27
21 SCT-7C	0.13	0.14	23.9	127.9	1650	2.20	34.6	7.37	9.8	0.20	0.9	0.030	0.66	10.5	25.0	1.63	1175	0.85	0.57
21 SCT-8C	0.12	0.08	23.4	171.2	2870	2.05	33.6	9.13	9.4	0.20	0.8	0.030	0.43	10.5	24.8	2.01	1415	1.10	0.33
22 AB1	0.82	0.12	37.4	34.4	2050	2.60	44.8	4.10	14.2	0.25	1.7	0.040	1.15	20.5	33.4	2.61	730	1.55	1.75
22 AB2	0.68	0.08	29.8	22.8	709	2.30	37.2	3.30	12.65	0.30	1.5	0.035	1.07	15.5	30.2	2.08	570	1.55	1.65
23AB 1S	0.64	0.12	33.1	29.1	528	2.62	131	3.70	13.75	0.13	2.1	0.035	1.28	12.9	34.9	2.69	667	0.87	1.20
23AB 2SA	0.65	0.13	42.4	32.3	3050	3.22	47.6	4.13	14.85	0.15	2.0	0.037	1.32	17.3	35.6	2.40	797	0.80	1.18
23AB 2SB	0.60	0.10	28.4	26.8	315	2.48	39.8	3.63	13.1	0.13	1.6	0.028	1.30	12.4	33.5	2.77	651	0.78	1.11
22 LS 1SA	0.96	0.12	35.1	34.5	883	2.50	42.0	4.09	14.25	0.30	1.6	0.040	1.18	19.5	30.0	2.75	945	3.20	1.69
22 LS 1SB	0.69	0.08	26.5	26.7	653	2.10	32.2	3.56	12.7	0.30	1.5	0.035	1.04	14.0	27.0	2.20	535	0.75	1.76
22 LS 2	0.76	0.08	31	27.8	1510	2.55	48.8	4.05	14.1	0.30	1.7	0.045	1.09	16.5	30.6	2.04	750	1.00	1.66
22 LS 3	0.7	0.08	33.4	19.1	1070	2.30	35.6	3.47	12.8	0.25	1.6	0.040	1.09	18.0	28.4	1.83	510	0.75	1.81

Table 3 (continued). Mercury and associated major and minor elements in sediment, precipitates, and calcine samples from Contact and Sonoma Mines and Anna Belcher and Little Sulphur Creek watersheds, Sonoma County, California.

Field number	Nb ppm	Ni ppm	P ppm	Pb ppm	Rb ppm	Re ppm	S %	Sb ppm	Se ppm	Sn ppm	Sr ppm	Ta ppm	Te ppm	Th ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm	Au ppm
21CT 2S	5.5	447	420	13.0	44.8	<0.002	0.03	0.70	<1	1.4	83.6	0.45	0.30	4.6	0.24	0.28	1.1	102	<0.1	11.5	78	55.0	
23CT 1S	6.4	216	530	13.5	74.6	<0.002	0.03	0.84	<1	1.5	92.9	0.19	0.05	7.1	0.459	0.42	1.9	134	0.9	18.9	90	71.1	
23CT 2S	6.1	476	500	10.6	59.3	<0.002	0.03	0.91	<1	1.5	75.4	0.25	0.05	5.1	0.354	0.33	1.1	131	0.7	13.3	86	57.7	
21- CT-OR	<0.1	810	<10	1	0.5	<0.002	0.21	0.25	<1	0.8	73.3	<0.05	0.25	<0.2	0.01	0.16	<0.1	19	<0.1	0.5	22	2.5	
21-CT - C1	0.7	1255	50	6.5	4.2	<0.002	0.06	0.75	1	1.0	354	<0.05	1.35	0.4	0.04	0.12	0.1	36	<0.1	1.7	36	7.5	
21-CT - C2	0.3	1705	40	2.0	2.0	0.002	0.1	0.30	<1	1.0	186.5	<0.05	0.90	<0.2	0.03	0.10	<0.1	34	<0.1	0.9	36	3.5	
21-CT - C3	2.7	1455	180	6.0	19.3	0.002	0.06	0.90	<1	1.2	122	0.20	1.95	2.0	0.13	0.24	0.6	68	<0.1	4.3	58	22.5	
21-CT - C4	0.7	1755	40	6.0	4.1	<0.002	0.07	0.45	1	0.4	264	<0.05	1.40	0.2	0.04	0.14	0.1	38	<0.1	1.5	40	6.0	
21-CT - C5	0.8	1655	50	3.5	4.8	<0.002	0.04	0.55	<1	0.4	232	<0.05	2.80	0.2	0.05	0.14	0.1	40	<0.1	1.7	36	6.0	
21-CT - 6C	3.4	1255	200	7.5	8.6	<0.002	0.08	0.55	<1	1.2	180.5	0.25	1.45	2.2	0.16	0.20	0.4	79	<0.1	6.0	70	23.0	
21-CT - C7	6.7	377	370	9.5	46.3	0.002	0.05	1.00	<1	1.2	126	0.60	0.35	5.0	0.30	0.28	1.2	112	<0.1	12.3	74	55.5	
21-CT - C8	3.9	2880	520	9.5	30.2	<0.002	0.03	1.10	1	1.0	42.2	0.30	<0.05	3.2	0.19	0.42	0.6	95	<0.1	8.3	94	27.0	
21CT0401C1	1.3	1875	70	9.5	8.7	<0.002	0.05	1.20	<1	1.8	179.5	0.05	2.10	0.8	0.07	0.14	0.2	53	<0.1	2.8	58	10.5	
CT0404C2	0.6	1590	30	3.5	3.9	0.002	0.04	0.35	<1	0.2	242	<0.05	0.80	0.2	0.04	0.10	<0.1	33	<0.1	1.2	34	5.0	
21 CT 50	4.9	906	270	9.0	22.1	0.002	0.07	1.05	<1	1.2	260	0.35	<0.05	2.8	0.24	0.26	0.7	90	0.6	8.4	60	29.5	<5
21 SCT-3C	3.8	2890	570	9.0	29.3	0.002	0.03	1.30	<1	0.6	43.6	0.30	<0.05	3.4	0.21	0.40	0.7	106	0.7	8.5	140	25.0	10
21 CT 3S	5.6	1580	300	10.0	35.7	0.002	0.01	1.65	<1	1.	82.2	0.40	0.05	4.4	0.29	0.30	1.0	115	0.8	10.5	90	35.0	<5
21 SCT-5C	5.8	487	590	95.5	8.1	0.006	0.12	1.10	4	3.2	60	0.10	<0.05	2.0	0.23	0.08	0.6	182	<0.1	9.1	342	21.0	210
21 SCT-6C	3.4	3140	350	9.0	20.1	0.002	0.04	1.10	1	0.6	36.2	0.25	0.05	2.6	0.17	0.34	0.6	79	1.0	6.8	76	22.0	10
21 SCT-7C	4.0	2080	330	12.5	31.5	0.002	0.03	1.10	<1	0.8	35.4	0.30	0.05	3.2	0.21	0.34	0.7	86	0.7	7.9	76	24.5	<5
21 SCT-8C	3.8	2860	400	7.5	26.0	<0.002	0.02	1.15	<1	0.8	40.2	0.30	<0.05	3.0	0.19	0.38	0.7	85	0.8	8.2	80	24.0	<5
22 AB1	6.8	309	490	17.5	48.3	0.002	0.07	0.85	1	3.0	111.5	0.25	<0.05	5.8	0.34	0.28	1.5	115	0.7	13.3	94	51.0	
22 AB2	6.4	221	450	11.0	45.2	0.002	0.04	0.65	1	1.6	97.9	0.25	<0.05	4.8	0.29	0.26	1.3	94	0.7	11.6	74	47.0	
23AB 1S	5.2	306	420	10.6	56.4	<0.002	0.04	0.84	<1	1.4	80.3	0.22	0.05	5.0	0.324	0.30	1.2	114	0.8	12.0	79	56.8	
23AB 2SA	5.1	275	520	11.8	61.3	<0.002	0.06	0.68	1	2.4	91.3	0.13	<0.05	5.9	0.406	0.34	1.5	138	0.7	15.0	106	55.7	
23AB 2SB	4.8	314	430	9.0	55.6	<0.002	0.02	0.71	<1	1.2	72	0.09	<0.05	5.0	0.318	0.30	1.2	112	0.7	11.8	77	45.4	
22 LS 1SA	6.6	352	530	12.5	51.0	0.004	0.04	0.70	1	1.2	116	0.25	<0.05	5.8	0.32	0.30	1.5	113	0.8	12.7	90	48.5	
22 LS 1SB	6.9	264	370	9.0	45.7	0.002	0.01	0.65	1	1.2	92.9	0.25	<0.05	5.0	0.31	0.24	1.4	98	0.9	10.6	78	46.0	
22 LS 2	5.3	248	450	11.0	49.9	0.004	0.01	0.55	1	1.2	96	0.15	<0.05	5.4	0.35	0.32	1.5	122	0.6	12.9	90	52.5	
22 LS 3	5.1	191	420	10.5	45.9	0.002	0.02	0.45	1	1.0	101	0.15	<0.05	6.2	0.33	0.26	1.5	103	0.5	11.3	82	49.0	

Table 4. Total mercury (Hg_T) and monomethyl mercury (MMeHg) in individual composites of invertebrates collected at Anna Belcher Creek, Contact Mine, and Sonoma Pond, Sonoma County, California, in 2003, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Unique sample code	Site code	Order	Family	Common name	Collection date	No. of specimens	Sample mass (g)	Ave. mass (g)	MMeHg, µg/g (wet)	Hg _T , µg/g (wet)	Moisture (percent)
CR-ABCM-040103-001	ABCM	Hemiptera	Gerridae	Water Striders	4/1/2003	17	1.33	0.078	0.116	0.131	63.3
CR-ABCM-040103-002	ABCM	Megaloptera	Corydalidae	Dobsonflies	4/1/2003	5	1.91	0.382	0.170	0.391	80.4
CR-ABCM-040103-003	ABCM	Megaloptera	Corydalidae	Dobsonflies	4/1/2003	5	1.11	0.222	0.092	0.199	82.7
CR-ABCM-040103-004	ABCM	Megaloptera	Corydalidae	Dobsonflies	4/1/2003	9	1.31	0.146	0.253	0.429	78.2
CR-ABTF-040103-001	ABTF	Hemiptera	Gerridae	Water Striders	4/1/2003	19	1.31	0.069	0.128	0.137	59.2
CR-ABTF-040103-002	ABTF	Hemiptera	Gerridae	Water Striders	4/1/2003	19	1.22	0.064	0.144	0.142	60.4
CR-ABTF-040103-003	ABTF	Megaloptera	Corydalidae	Dobsonflies	4/1/2003	1	0.49	0.490	0.495	0.692	83.0
CR-ABTF-040103-006	ABTF	Odonata	Aeshnidae	Dragonflies	4/1/2003	5	0.99	0.198	0.192	0.207	80.6
CR-ABTF-040103-007	ABTF	Odonata	Gomphidae	Dragonflies	4/1/2003	2	0.57	0.285	0.247	0.360	74.4
CR-ABTF-040103-008	ABTF	Odonata	Cordulegastri dae	Dragonflies	4/1/2003	1	1.34	1.340	0.258	0.368	72.3
CR-ABTF-040103-004	ABTF	Plecoptera	Perlidae	Stoneflies	4/1/2003	5	1.32	0.264	0.174	0.222	71.6
CR-ABTF-040103-005	ABTF	Plecoptera	Perlidae	Stoneflies	4/1/2003	10	1.37	0.137	0.139	0.141	74.4
CR-ABUS-040103-001	ABUS	Hemiptera	Gerridae	Water Striders	4/1/2003	25	1.71	0.068	0.124	0.139	60.2
CR-ABUS-040103-002	ABUS	Odonata	Aeshnidae	Dragonflies	4/1/2003	7	1.08	0.154	0.172	0.243	79.6
CR-ABUS-040103-003	ABUS	Odonata	Aeshnidae	Dragonflies	4/1/2003	7	1.21	0.173	0.195	0.202	80.4
CR-SOPD-040103-001	SOPD	Hemiptera	Gerridae	Water Striders	4/1/2003	20	1.37	0.069	0.243	0.326	59.0
CR-SOPD-040103-002	SOPD	Hemiptera	Corixidae	Water Boatmen	4/1/2003	20	1.26	0.063	0.498	0.462	69.5
CR-SOPD-040103-003	SOPD	Hemiptera	Corixidae	Water Boatmen	4/1/2003	20	1.35	0.068	0.660	0.525	69.8
BY-BH20-100199-001	BR20	Hemiptera	Gerridae	Water strider	1999	21	1.07	0.051	0.027	NA ¹	57.2
BY-BH20-091200-001	BR20	Hemiptera	Gerridae	Water strider	2000	26	1.30	0.050	0.027	0.028	76.1
BY-BH20-091501-003	BR20	Hemiptera	Gerridae	Water strider	2001	25	1.25	0.050	0.050	0.070	64.7
BY-BR20-082302-001	BR20	Hemiptera	Gerridae	Water strider	2002	25	1.37	0.055	0.041	0.045	63.0
BY-BH20-091200-004	BR20	Megaloptera	Corydalidae	Dobsonflies	2000	1	1.52	1.520	0.038	0.035	74.9
BY-BH20-091501-002	BR20	Megaloptera	Corydalidae	Dobsonflies	2001	4	0.61	0.153	0.040	0.041	79.6
BY-BH20-091501-001	BR20	Megaloptera	Corydalidae	Dobsonflies	2001	4	3.48	0.870	0.029	0.040	75.7
BY-BR20-082302-002	BR20	Megaloptera	Corydalidae	Dobsonflies	2002	2	3.03	1.515	0.048	0.050	71.2
BY-BH20-091501-009	BR20	Odonata	Aeshnidae	Dragonfly	2001	7	3.89	0.556	0.014	0.022	81.9
BY-BR20-082302-005	BR20	Odonata	Aeshnidae	Dragonfly	2002	8	3.63	0.454	0.026	0.024	79.9
BY-BH20-100199-002	BR20	Plecoptera	Perlidae	Stoneflies	1999	14	1.94	0.139	0.039	0.037	69.2
BY-BH20-091200-002	BR20	Plecoptera	Perlidae	Stoneflies	2000	5	1.20	0.240	0.068	NA	68.9
BY-BH20-091501-006	BR20	Plecoptera	Perlidae	Stoneflies	2001	12	2.51	0.209	0.060	0.076	69.3
BY-BH20-091501-007	BR20	Plecoptera	Perlidae	Stoneflies	2001	12	1.72	0.143	0.058	0.056	72.2
BY-BR20-082302-004	BR20	Plecoptera	Perlidae	Stoneflies	2002	12	1.53	0.128	0.044	0.052	68.8

Table 5. Total mercury (Hg_T) (µg/g, wet wt) in fish collected at Anna Belcher Creek sites (ABTF and ABUS), Sonoma County, California, in 2003 and a reference site at Bear River (BR20), 1999.

Sample code	Site acronym	Collection date	Common name	Species	Total length (millimeters)	Sample mass (g)	Hg _T (µg/g, wet weight)	Moisture (percent)
CR-ABTF-040103-001F	ABTF	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	104	11.71	0.114	76.9
CR-ABTF-040103-002F	ABTF	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	112	15.36	0.221	74.9
CR-ABTF-040103-003F	ABTF	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	131	24.24	0.219	75.9
CR-ABTF-040103-004F	ABTF	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	133	27.58	0.172	75.6
CR-ABTF-040103-005F	ABTF	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	152	35.85	0.200	74.2
CR-ABUS-040103-001F	ABUS	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	108	14.34	0.145	73.6
CR-ABUS-040103-002F	ABUS	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	110	14.27	0.171	71.7
CR-ABUS-040103-003F	ABUS	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	135	25.95	0.180	74.3
CR-ABUS-040103-004F	ABUS	4/2/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	143	26.30	0.171	72.5
CR-ABUS-040103-005F	ABUS	4/1/2003	Rainbow trout	<i>Oncorhynchus mykiss</i>	141	33.04	0.219	73.5
R-075	BR20	8/26/1999	Brown trout	<i>Salmo trutta</i>	230	118.0	0.063	80.2
R-076	BR20	8/26/1999	Brown trout	<i>Salmo trutta</i>	255	177.0	0.050	75.4
R-077	BR20	8/26/1999	Brown trout	<i>Salmo trutta</i>	265	180.0	0.082	76.3
F-029	BR20	8/26/1999	Brown trout	<i>Salmo trutta</i>	295	275.0	0.095	77.8

Table 6. Mercury (Hg_T) and monomethylmercury (MMeHg) concentrations in water and sediment samples from Contact Mine and downstream waters, Sonoma County, California.

Sample number	Date	Water			Sediment		
		Hg total ng/L	Hg filtered ng/L	Total MMeHg ng/L	Hg ng/g	MMeHg ng/g	Percent MMeHg (MMeHg/Hg)
	Contact Mine						
21CT1	4/20/2001	181	31.70	0.102			
21CT2	4/20/2001	104	8.46	0.046	10,800	0.78	0.007
21CT3	4/20/2001	13,900	0.99	17.0			
21CT4	4/20/2001						
23CT1	4/1/2003	12	5.50	2.48	662	14.20	2.145
23CT2	4/1/2003	40.1	6.47	<0.025	5,240	0.536	0.010
	Anna Belcher Creek						
23AB1	4/1/2003	9.2	5.64	0.088	2,900	0.43	0.015
23AB2	4/1/2003	13.7	5.48	0.131	50,600	2.57	0.005
	Little Sulphur Creek						
23LS1	4/20/2001	2.45	1.61	0.048	206	0.139	0.067

Table 7. Table 7. Concentration of anions and selected cations in filtered water samples from Anna Belcher Creek, Little Sulphur Creek, and Contact Mine, Sonoma County, California.

Sample number	Cl ppm	F ppm	NO ₃ ppm	SO ₄ ppm	CaCO ₃ ppm	Ca mg/L	Fe mg/L	Mg mg/L	K mg/L	Li µg/L	Na mg/L
Contact Mine											
21CT1	2.4	1.3	0.10	20.0	240	40	<.02	32	0.85	4.4	8.9
21CT2	2.6	0.1	<0.08	7.2	170	15	<.02	34	0.39	<1	3.0
21CT3	2.3	0.1	0.10	7.8	300	11	0.024	64	0.30	1.2	1.6
21CT4	2.8	0.2	<0.08	16.0	440	7.8	<.02	100	0.23	6.6	1.4
23CT1C	2.5	0.2	<.08	9.9	92	14.4	0.340	14	0.75	<1	3.5
23CT2C	2.4	0.1	<.08	6.3	150	12.3	0.079	29.5	0.39	<1	2.8
Anna Belcher Creek											
23AB1C	2.5	0.2	<.08	9.2	140	21	<0.02	21.5	0.66	<1	4.4
23AB2C	2.5	0.2	<.08	8.5	130	21	<0.02	20.8	0.70	<1	4.3
Little Sulphur Creek											
22LS1C	2.0	0.1	<.08	7.8	120	22.2	<0.02	15.6	0.31	<1	5.6

Table 8. Major- and minor- element concentrations in filtered water samples from the Contact and Sonoma Mine areas and Anna Belcher and Little Sulphur Creeks, Sonoma County, California.

Sample number	Al µg/L	B µg/L	Ba µg/L	Ca mg/L	Ce µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Gd µg/L	K µg/L	La µg/L	Li µg/L	Mg mg/L
Contact Mine														
23CT1B	1.0	14	88	14.0	0.056	0.27	<1	0.5	90	0.014	480	0.04	< 0.1	13.6
23CT2B	0.8	26	97	11.7	< 0.01	<0.02	4.1	0.5	12	< 0.01	250	0.02	0.49	27.9
Anna Belcher Creek														
23AB1B	2.0	20	110	20.1	0.012	<0.02	1.4	<0.5	25	0.007	410	0.02	1.00	20.5
23AB2B	<0.5	19	19	20.7	< 0.01	<0.02	7.5	<0.5	22	< 0.01	410	< .01	< 0.1	20.6
Little Sulphur Creek														
22LS1C	0.7	15	57	23.2	0.220	<0.02	<1	<0.5	28	0.008	190	0.04	0.10	16.2
22LS1D	<0.5	14	57	21.0	< 0.01	<0.02	<1	0.6	28	< .005	190	< .01	0.10	14.6
Sample	Mn µg/L	Mo µg/L	Na mg/L	Nd µg/L	Ni µg/L	Pb µg/L	Rb µg/L	SiO2 mg/L	Sr µg/L	U µg/L	V µg/L	W µg/L	Y µg/L	Zn µg/L
Contact Mine														
23CT1B	120	0.22	3.4	0.064	2.0	0.06	0.09	7	170	0.012	0.3	0.03	0.060	1.70
23CT2B	0.04	0.31	2.7	0.019	2.3	<0.05	0.14	13	160	0.011	0.8	< .03	0.025	0.87
Anna Belcher Creek														
23AB1B	0.33	0.29	4.2	0.017	1.2	<0.05	0.17	10	270	0.027	0.6	< .03	0.042	0.83
23AB2B	0.45	1.40	4.3	< 0.01	0.9	<0.05	0.17	12	230	0.011	2.0	0.94	0.014	<0.50
Little Sulphur Creek														
22LS1C	1.4	0.10	5.7	0.050	0.9	<0.05	0.11	15	160	0.018	2.1	<0.03	0.022	1.50
22LS1D	1.2	0.10	5.2	0.012	1.0	<0.05	0.11	15	160	0.018	2.1	<0.03	0.022	3.30

Note: Elements not detected (detection limit in parentheses): Ag (0.01), Au (0.01), As (2), Be (0.05), Bi (0.03), Cd (0.02), Cs (0.01), Dy (0.005), Er (0.005), Eu (0.005), Ga (0.02), Ge (0.02), Ho (0.005), In (0.01), Lu (0.1), P (3), Pr (0.01), Re (0.02), (Sb (0.1), Se (0.2), Sm (0.01), Tb (0.005), Th (0.04), Tl (0.1), Tm (0.005), Yb (0.01).

Table 9. Major and minor element concentrations in unfiltered waters from the Contact and Sonoma mines and Anna Belcher and Little Sulphur Creeks, Sonoma County, California.

Sample	Al µg/L	B µg/L	Ba µg/L	Ca mg/L	Ce µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Ge µg/L	K µg/L	Li µg/L	Mg mg/L	Mn µg/L
Contact Mine														
21CT1a	<0.01	98	250	40	< .01	<0.02	3	<0.5	<0.02	0.07	0.85	4.1	32	0.1
21CT2a	<0.01	34	99	15	< .01	<0.02	6	0.5	<0.02	< 0.02	0.39	0.4	34	0.1
21CT3a	0.027	28	71	11	0.04	0.06	4	0.9	0.02	< 0.02	0.30	1.1	64	0.8
21CT4a	<0.01	23	100	7.8	< .01	0.10	8	<0.5	<0.02	< 0.02	0.23	6.4	100	0.1
23CT1A	.048	16	91	14.4	0.14	0.32	<1	0.6	0.34	< 0.02	0.75	< 0.1	14	143
23CT2A	.066	28	99	12.3	0.06	0.09	3.6	0.6	0.08	< 0.02	0.39	0.6	29.5	<10
Anna Belcher Creek														
23AB1A	0.011	22	110	21	0.02	<0.02	1.6	<0.5	<0.02	< 0.02	0.66	1.2	21.5	<10
23AB2A	0.028	20	17	21	< .01	<0.02	7.6	<0.5	<0.02	< 0.02	0.7	< 0.1	20.8	<10
Little Sulphur Creek														
22LS1A	0.012	14	58	22.2	0.02	<0.02	<1	<0.5	<0.02	< 0.02	0.31	0.21	15.6	<10
22LS1B	<0.01	13	57	21	0.02	0.022	<1	<0.5	33	< 0.02	190	< 0.1	14.7	2.7
Sample	Mo µg/L	Na mg/L	Ni µg/L	P µg/L	Rb µg/L	Sb µg/L	SiO2 mg/L	Sr µg/L	U µg/L	V µg/L	W µg/L	Y µg/L	Yb µg/L	Zn µg/L
Contact Mine														
21CT1a	0.96	8.9	0.7	2	0.61	0.2	14	930	0.04	2	0.07	0.2	< 0.01	2
21CT2a	0.53	3.0	1.8	3	0.1	0.08	16	180	0.03	1	0.04	0.03	< 0.01	1
21CT3a	0.3	1.6	6.7	6	0.08	0.2	12	91	0.04	1	0.04	0.1	0.01	2
21CT4a	0.2	1.4	29.0	4	0.20	0.04	10	71	0.02	0.8	0.04	< 0.01	< 0.01	2
23CT1A	1.9	3.5	2.4	< 3	0.14	<0.1	7.5	180	0.03	0.6	0.07	0.09	< 0.01	0.6
23CT2A	0.92	2.8	3.0	< 3	0.16	<0.1	14	160	0.02	0.6	0.05	0.06	< 0.01	1
Anna Belcher Creek														
23AB1A	0.68	4.4	1.3	< 3	0.16	<0.1	10	260	0.03	0.7	0.04	0.04	< 0.01	0.9
23AB2A	5.2	4.3	0.9	< 3	0.16	0.2	12	220	0.02	2.1	1.5	0.02	< 0.01	<0.5
Little Sulphur Creek														
22LS1A	0.2	5.6	0.98	< 3	0.12	<0.1	16	160	0.02	2.1	0.04	0.02	< 0.01	8
22LS1B	0.15	5.2	0.99	< 3	0.10	<0.1	15	150	0.02	2.2	< 0.03	0.02	< 0.01	7.7

Notes: Elements not detected (detection limits in parentheses): Ag (0.01), As (2), Au (0.01), Be (0.05), Bi (0.12), Cd (0.02), Cs (0.01), Dy (0.02), Er (0.005), Eu (0.006), Ga (0.04), Gd (0.03), Ge (0.05), Ho (0.005), In (0.01), La (0.3), Pb (0.2), Pr (0.04), Re (0.02), Sb (0.3), Se (0.27), Sm (0.023), Tb (0.005), Th (0.6), Tl (0.1), Tm (0.005).

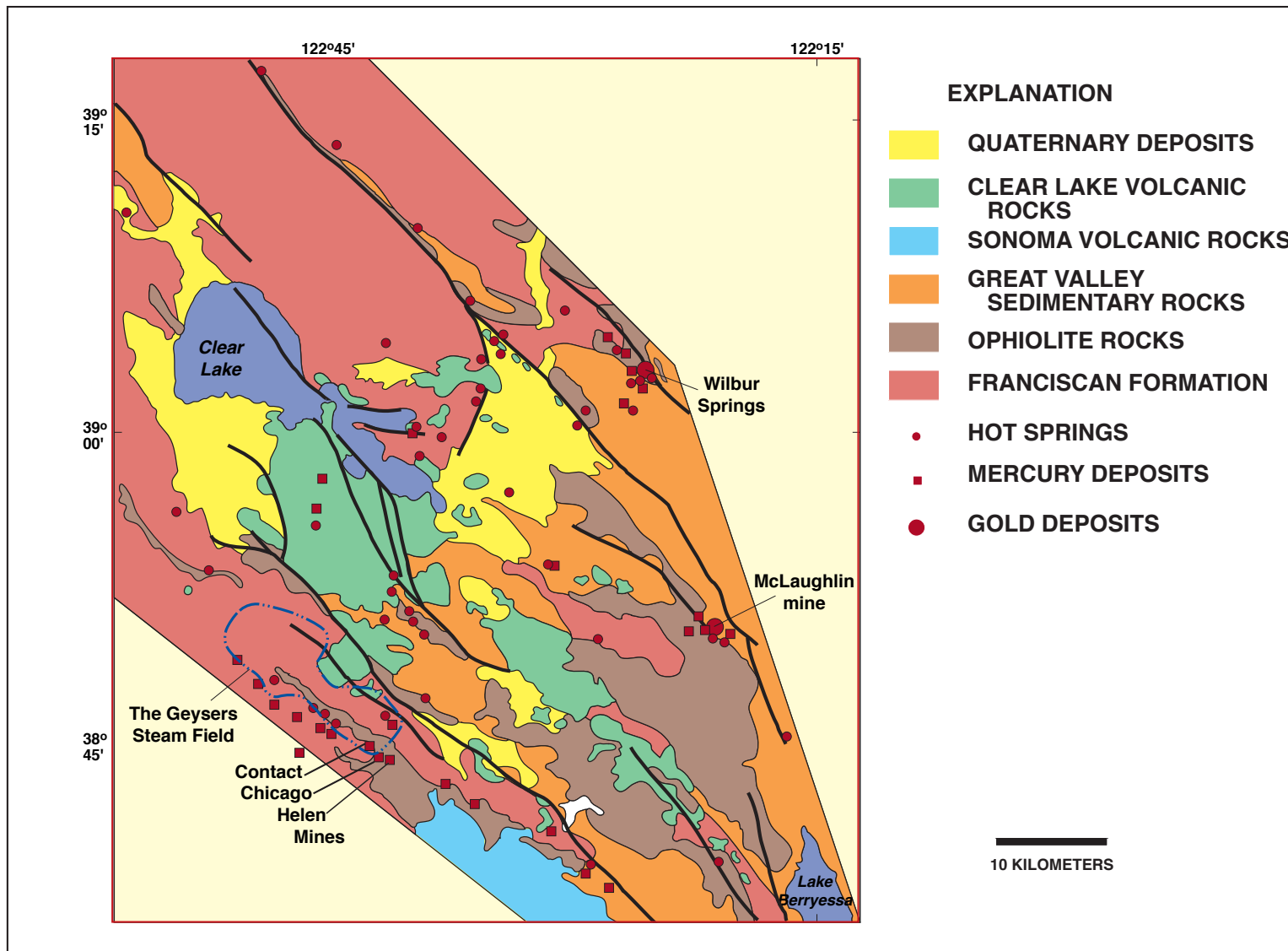


Figure 1. Geologic map of the Clear Lake volcanic field and location of the Contact mercury mine and other mines in the volcanic field.

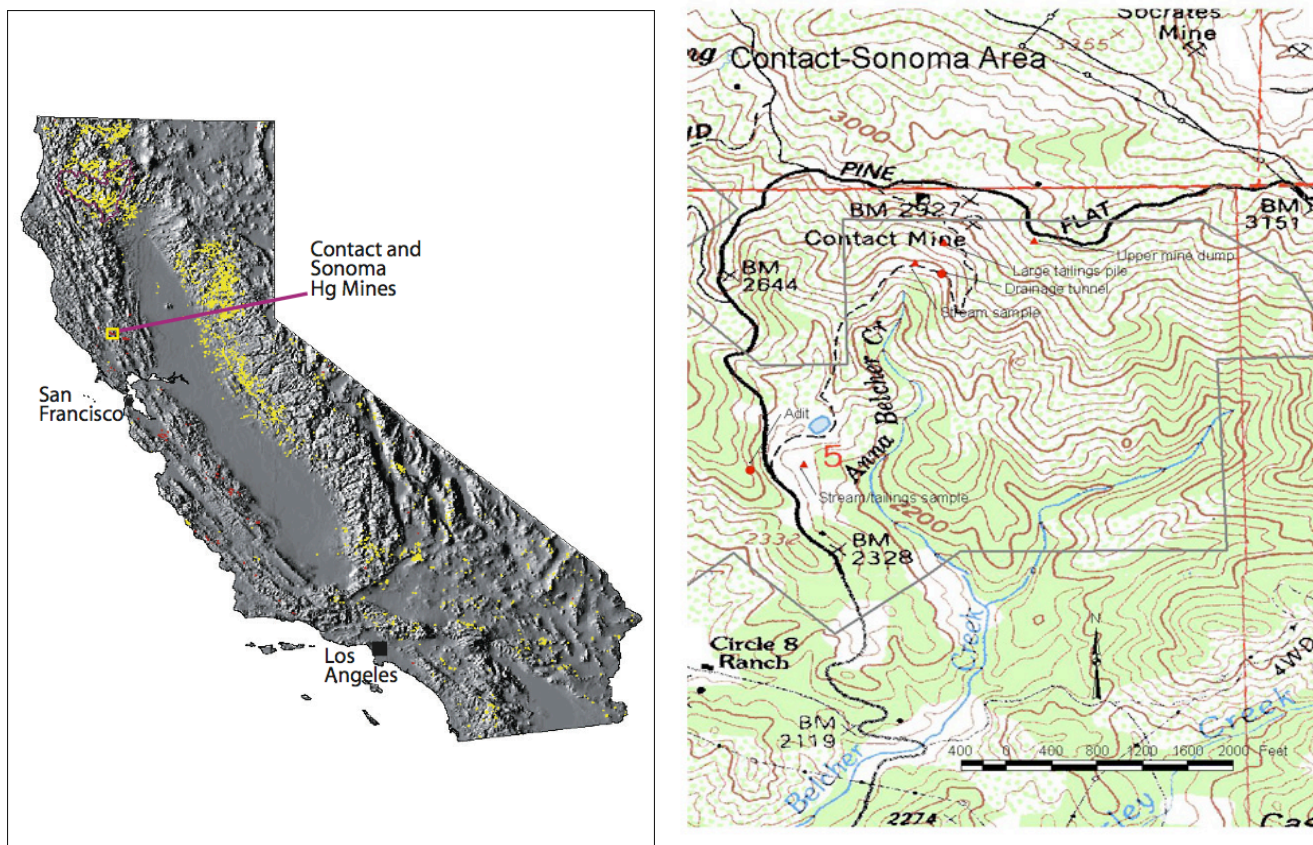


Figure 2. Location map of the Contact and Sonoma mercury mines and the upper part of Anna Belcher Creek. Sonoma Mine area located in area noted by “5” on the map (below pond).



Figure 3. Overview of Contact Mine area in the early the 1940s.



Figure 4. Overview of Contact Mine area from same perspective as in Fig. 3. Contact Mine calcines (in the distance) and pond (foreground) are located above the Sonoma Mine.

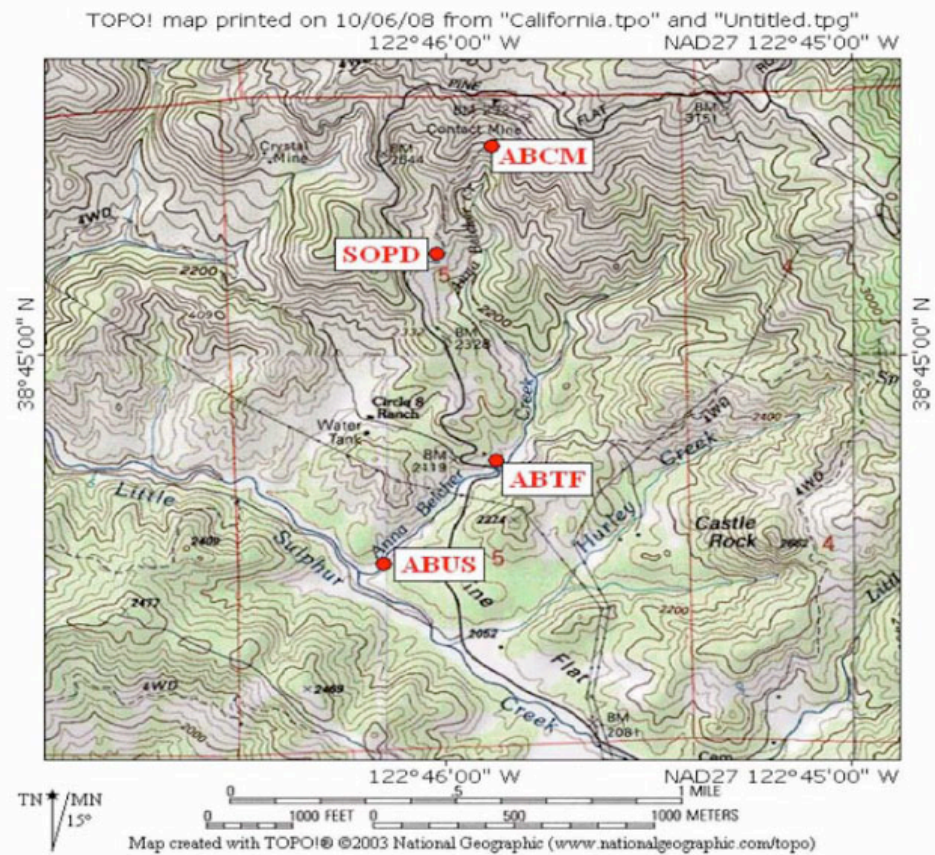


Figure 5. Locations of invertebrates and fish sampling sites, April 1, 2003.



Figure 6. Pond below Contact Mine area and above Sonoma Mine.



Figure 7. Sample sites 23CT-1 and SOPD at outlet of pond shown in figure 6, located below the Contact mine.



Figure 8. Unnamed creek that flows through the calcines at the Contact mine. Sample site 23CT-2 taken in creek below the calcines as shown in figure 2.

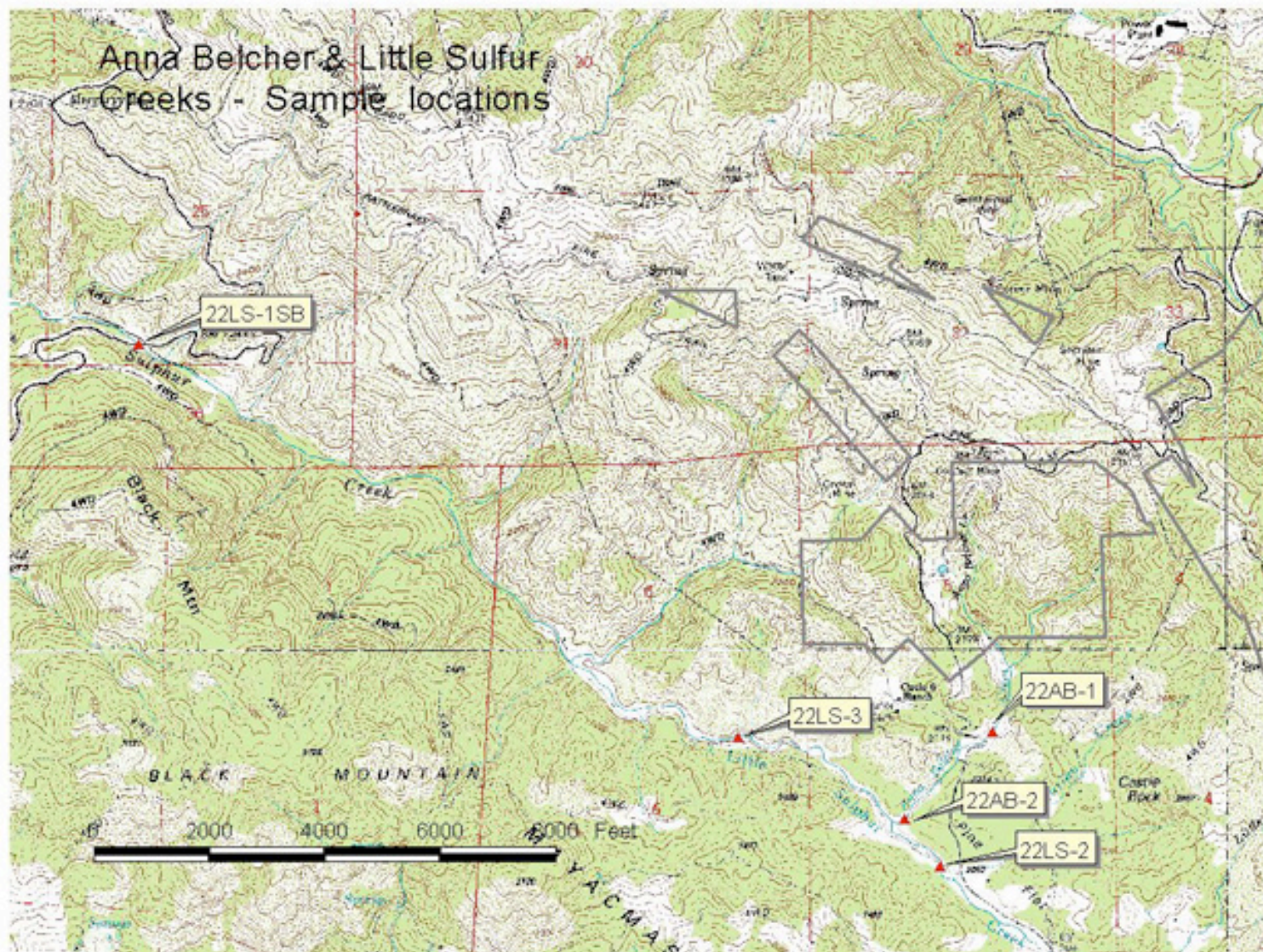


Figure 9. Map showing location of water, sediment and biota sites in the lower part of Anna Belcher Creek and the upper part of Little Sulphur Creek, Sonoma County, California.



Figure 10. Sample sites 23AB-1 and ABTF on Anna Belcher Creek at Twin Falls, located downstream from the Contact and Sonoma Mines, Sonoma County, California.



Figure 11. Sample site 23AB-2 and biota site ABUS on Anna Belcher Creek, upstream from the confluence with Little Sulphur Creek, Sonoma County, California.

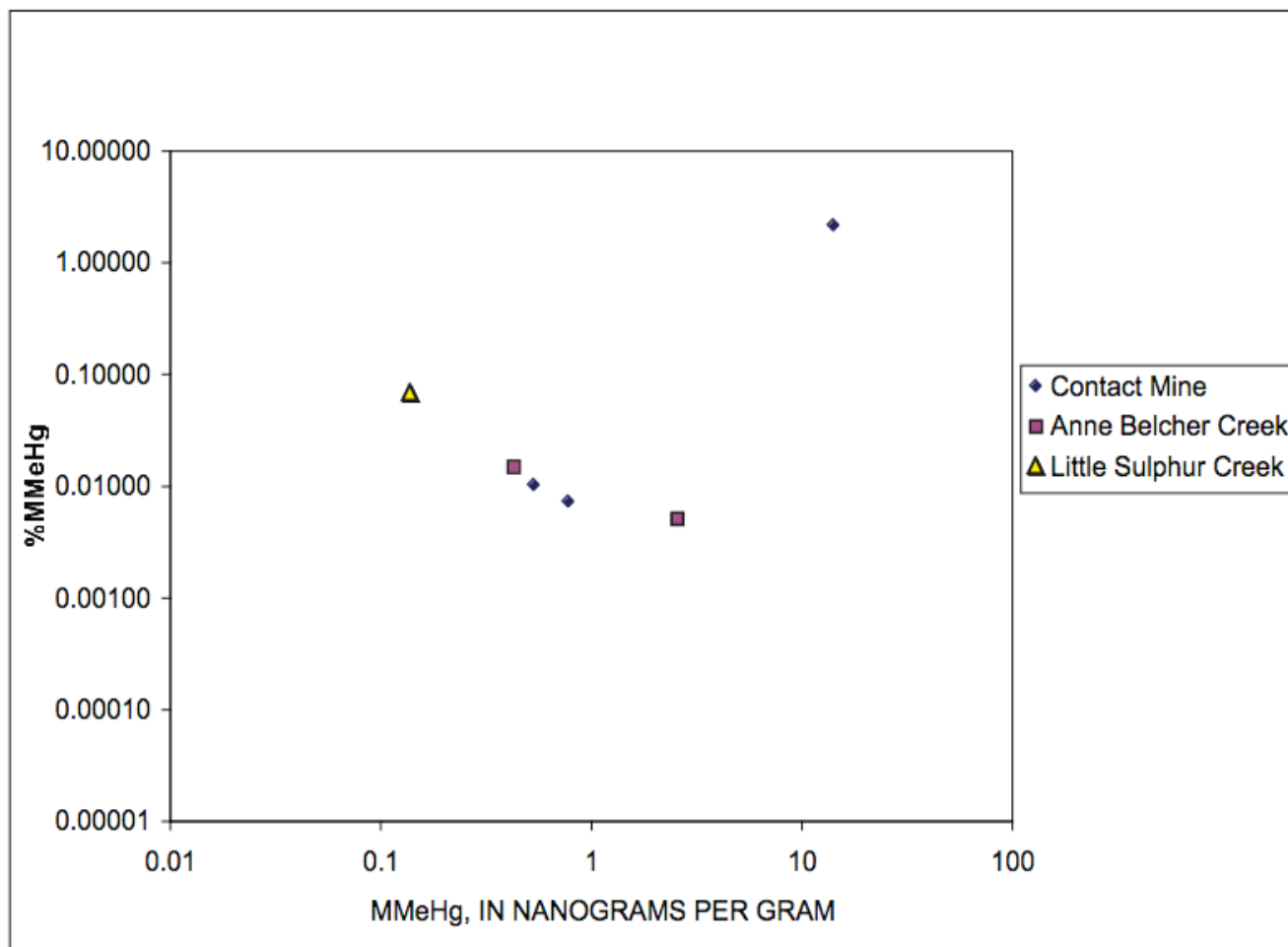


Figure 12. Log plot of % MMeHg verses MMeHg in sediment. The highest % MMeHg occurs in sediment from the pond above the Sonoma Mine.

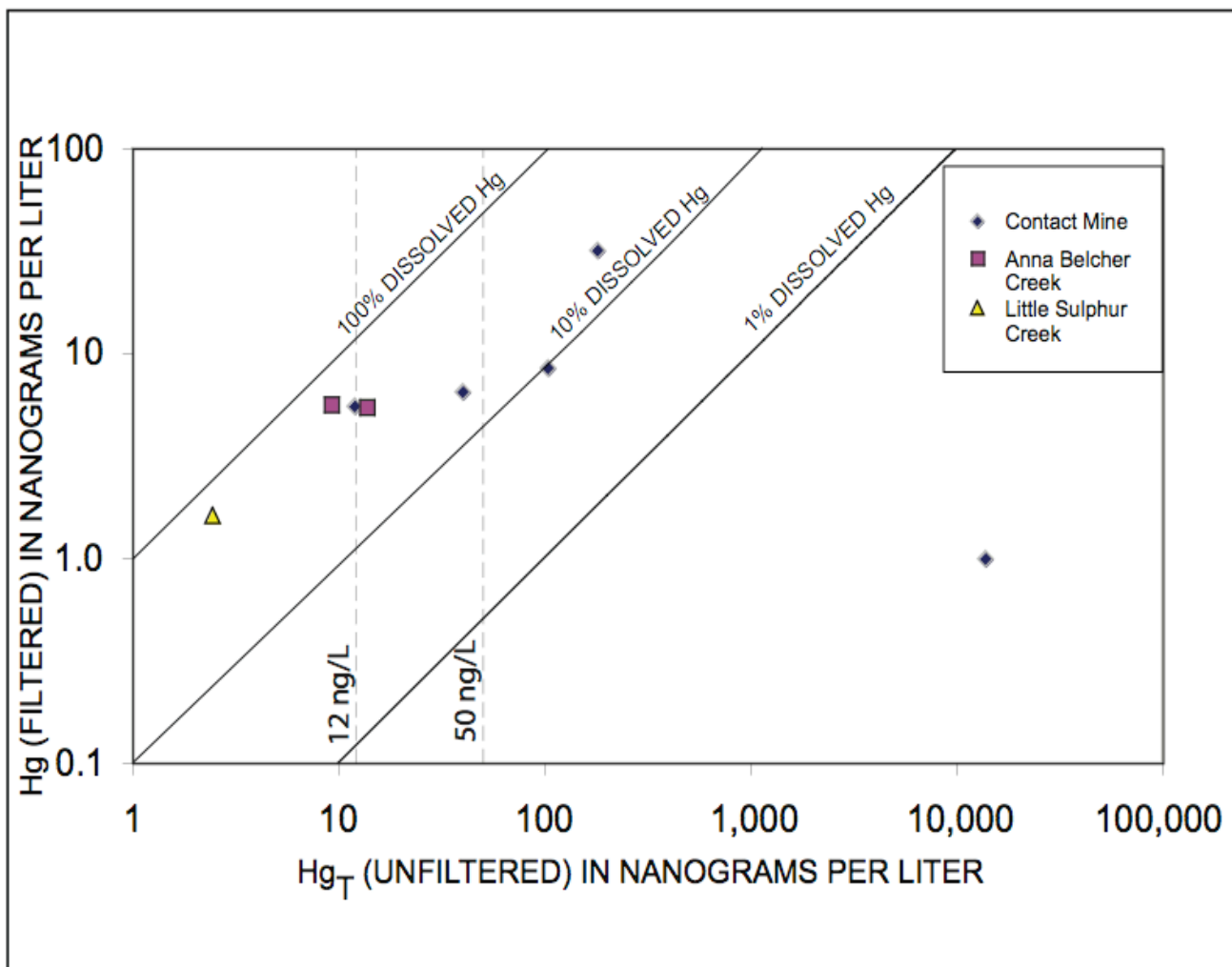


Figure 13. Log plot of dissolved Hg (filtered 0.45 μ m) verses total Hg, and USEPA water quality criterion of 50 nanograms per liter and water quality objective of 12 nanograms per liter total Hg.

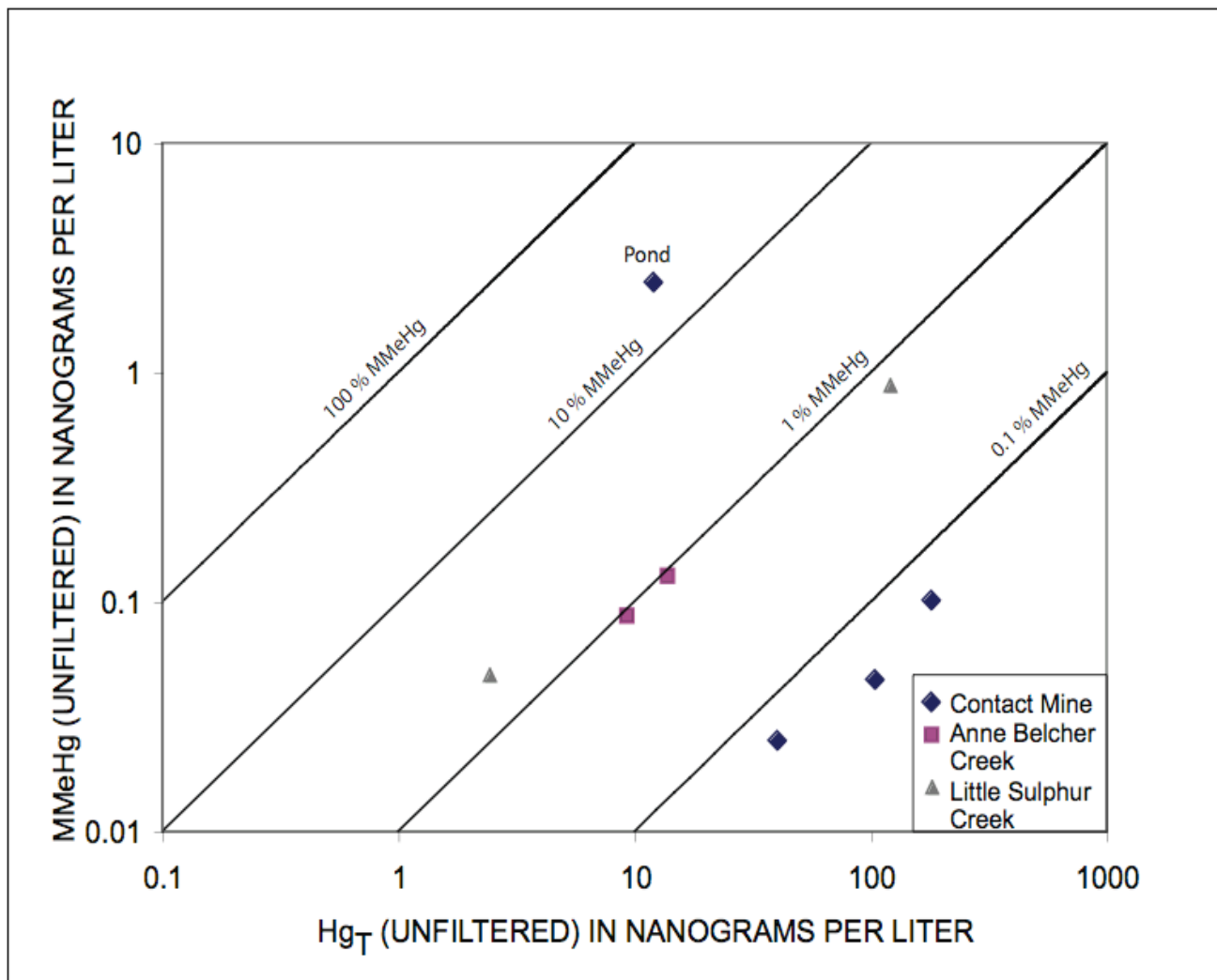


Figure 14. Log plot of total Hg verses total MMeHg. The sample from the pond above the Sonoma Mine has the highest MMeHg concentration and comprises the highest percent of total unfiltered Hg.

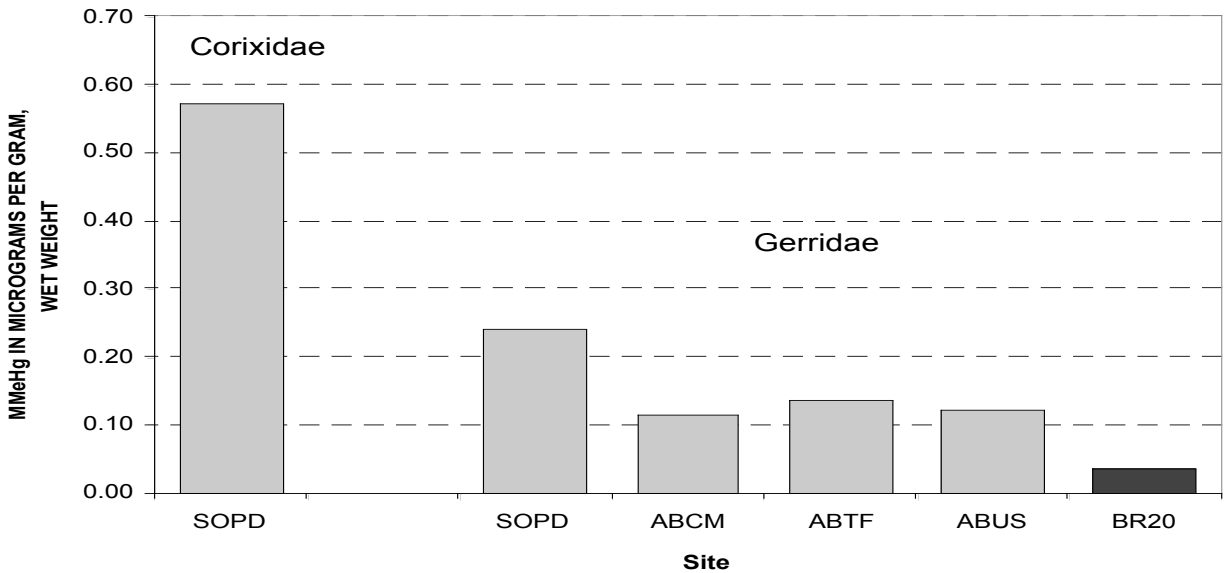


Figure 15. Concentrations of monomethylmercury (MMeHg, µg/g, wet weight) in individual composite samples of hemipterans (order Hemiptera, families Corixidae and Gerridae) collected from Anna Belcher sites in 2003 and the geometric mean MMeHg concentration (µg/g, wet wt) in Gerridae samples from reference site Bear River at the Highway 20 Bridge (BR20) during 1999-2002.

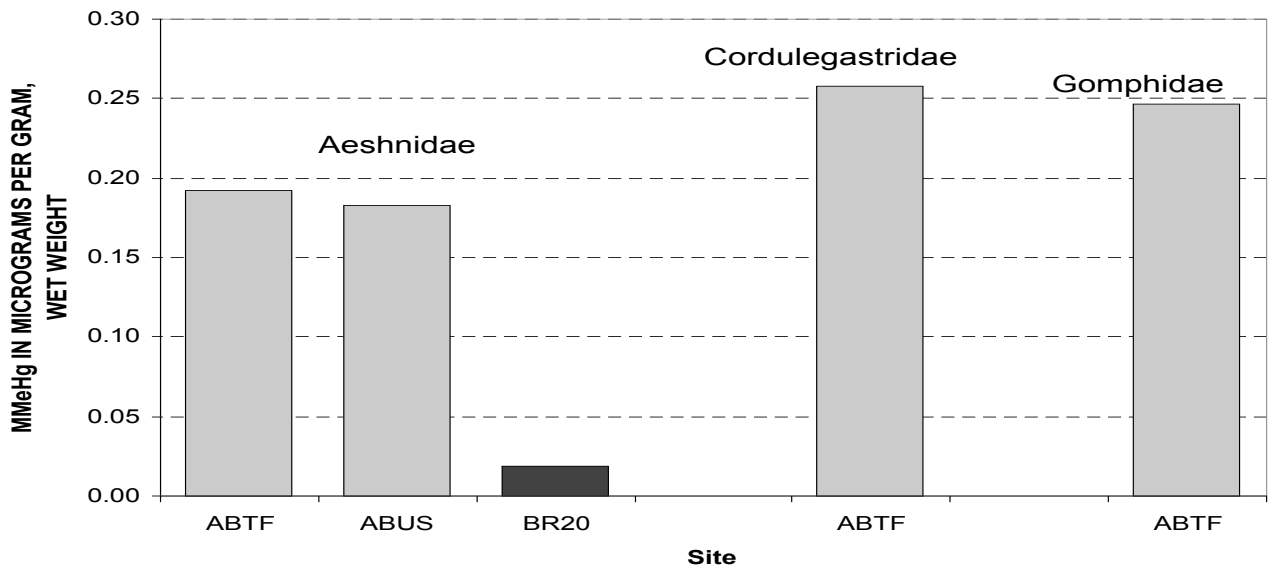


Figure 16. Concentrations of monomethylmercury (MMeHg, µg/g, wet weight) in individual composite samples of dragonflies (order Odonata, families Aeshnidae, Cordulegastridae, and Gomphidae) collected at Anna Belcher sites in 2003 and the geometric mean MMeHg concentration (µg/g, wet weight) in Aeshnidae samples from a reference site Bear River at the Highway 20 Bridge (BR20) during 1999-2002.

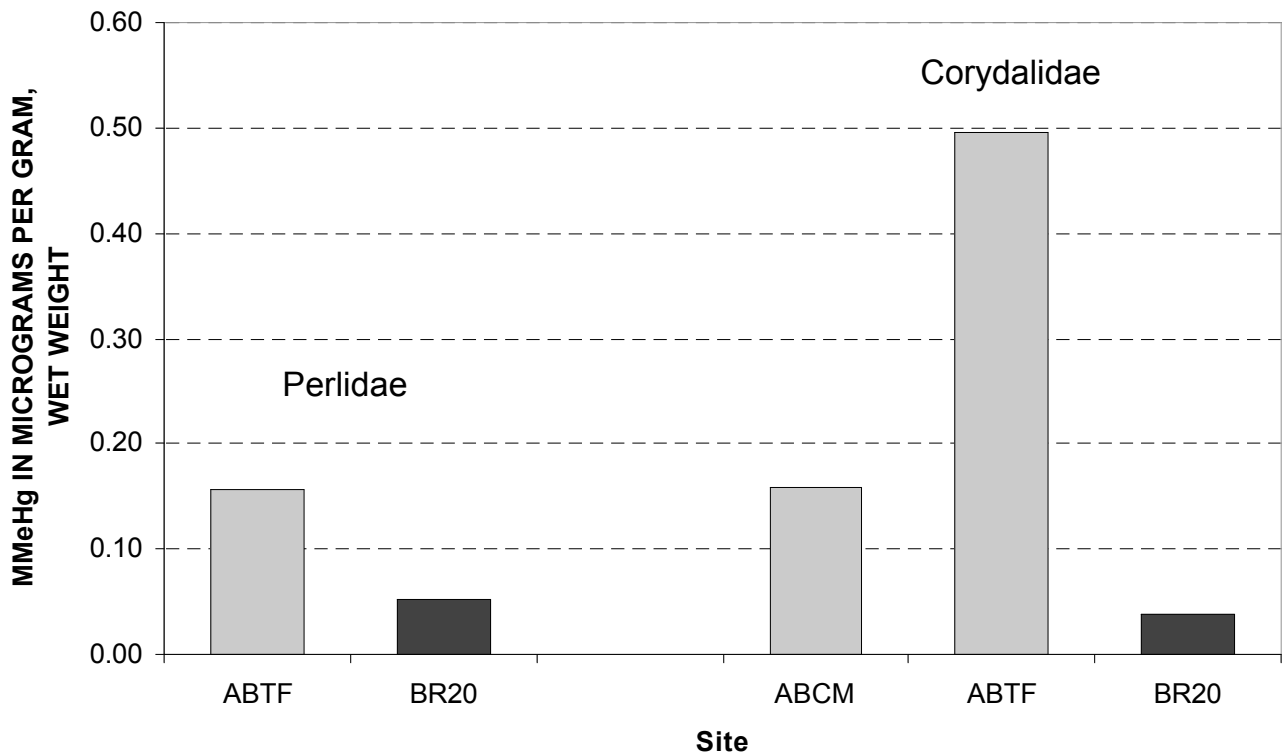


Figure 17. Concentrations of monomethylmercury (MMeHg, µg/g, wet weight) in individual composite samples of stoneflies (order Plecoptera, family Perlidae) and Dobsonflies (order Megaloptera, family Corydalidae) collected from Anna Belcher sites in 2003 and the geometric mean MMeHg concentrations (µg/g, wet weight) in the same taxa from reference site Bear River at the Highway 20 Bridge (BR20) during 1999-2002.

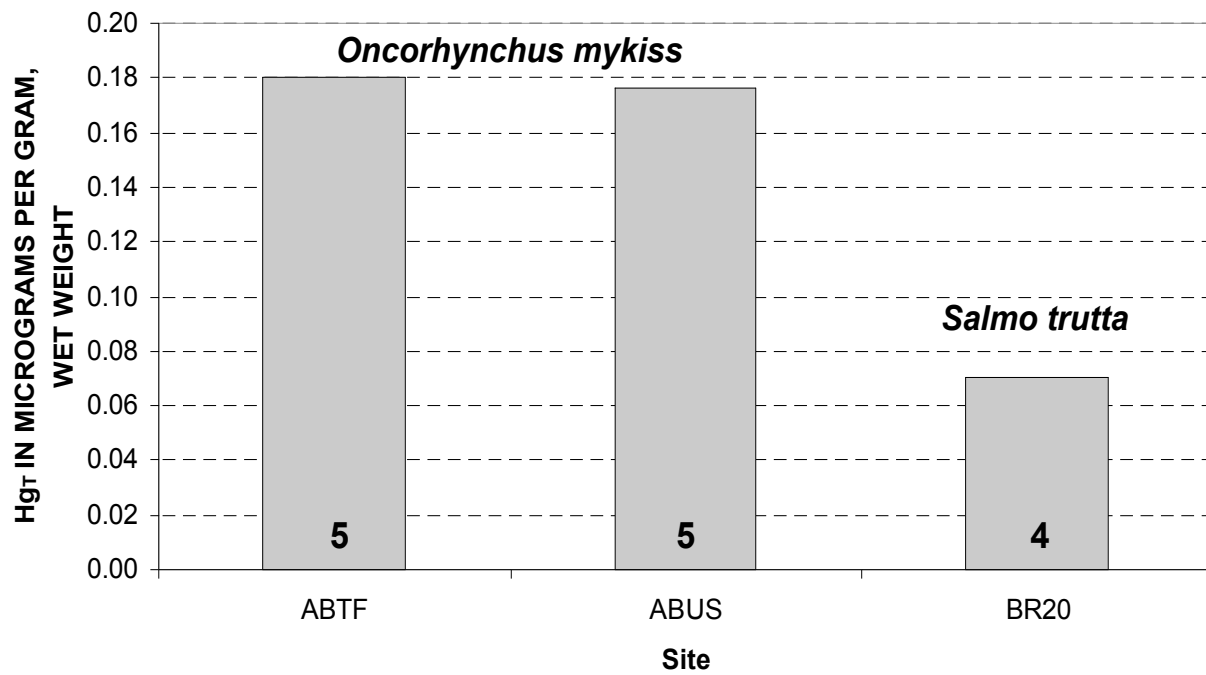


Figure 18. Geometric means of total mercury (Hg_T, μg/g, wet weight) in individual rainbow trout (*Oncorhynchus mykiss*) samples collected from two Anna Belcher Creek sites in April, 2003 and in fillets of brown trout (*Salmo trutta*) samples from a reference site Bear River at the Highway 20 Bridge (BR20) in 1999.

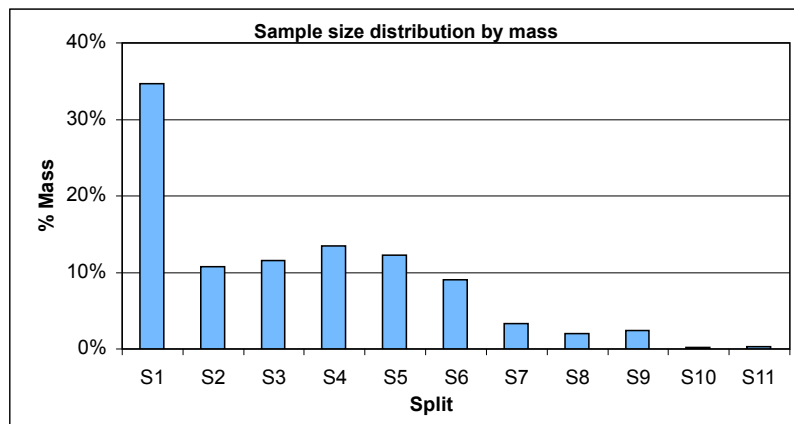
Appendix 1. Contact Mine calcine particle size and mass distribution and element concentrations as a function of grain size.

Sample Information	
Sample ID:	21CT50
Sample Description:	Contact Mine
Date Sieved:	5/6/05
Name:	James Akau

Initial Mass measurement	
Trial	Mass (g)
1	296.5
2	231.3
3	207.5
4	224.2
5	211.6
6	243.2
7	
8	
9	
10	
Total initial mass (g):	
	1414.3

Particle Diameter (dp)	Split	% mass
dp > 2830 um	S1	34.7%
2830 um > dp > 1700 um	S2	10.8%
1700 um > dp > 1000 um	S3	11.6%
1000 um > dp > 500 um	S4	13.5%
500 um > dp > 250 um	S5	12.2%
250 um > dp > 125 um	S6	9.0%
125 um > dp > 75 um	S7	3.3%
75 um > dp > 45 um	S8	2.0%
45 um > dp > 32 um	S9	2.4%
32 um > dp > 20 um	S10	0.2%
dp < 20 um	S11	0.3%

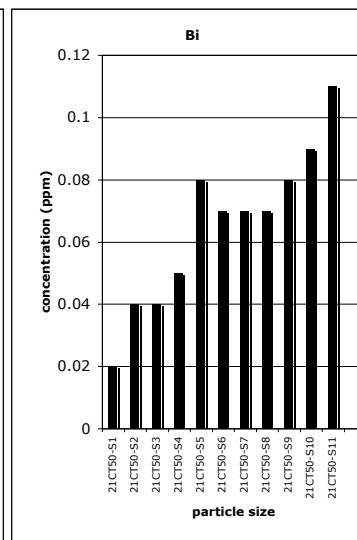
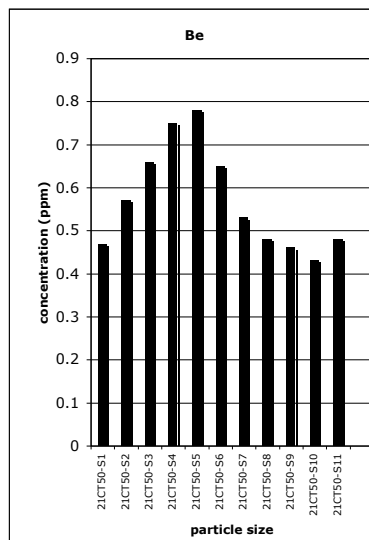
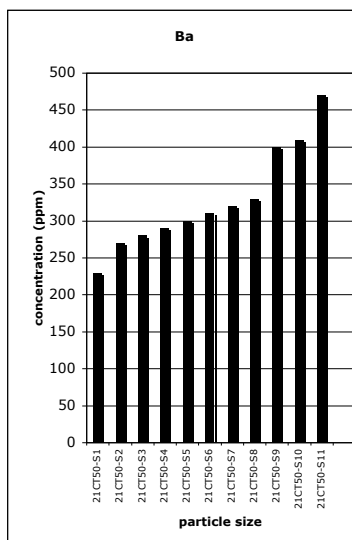
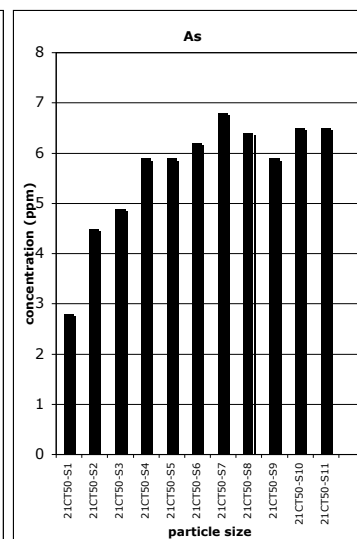
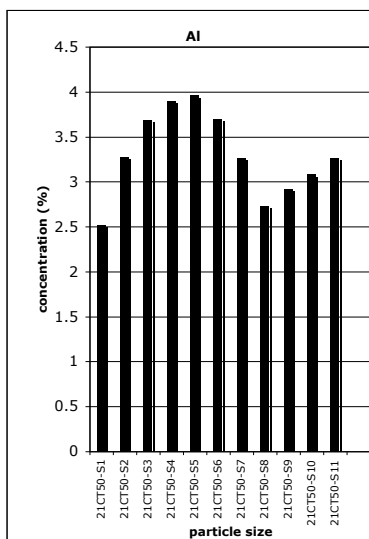
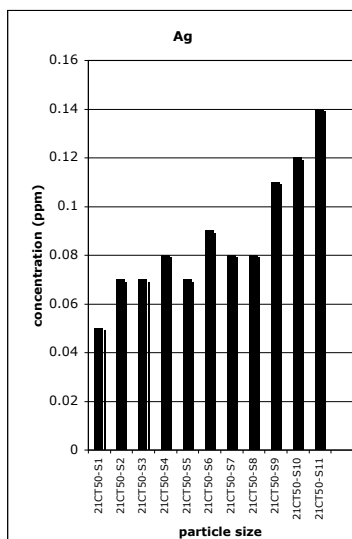
Sample split information	
21CT50 S1 dn > 2830 um	
Total	492.8 g
Chemex	246.4 g
Archive	246.4 g
21CT50 S2 2830 um > dn > 1700 um	
Total	152.7 g
Chemex	76.35 g
Archive	76.35 g
21CT50 S3 1700 um > dn > 1000 um	
Total	164.8 g
Chemex	82.4 g
Archive	82.4 g
21CT50 S4 1000 um > dn > 500 um	
Total	191.4 g
Chemex	95.7 g
Archive	95.7 g
21CT50 S5 500 um > dn > 250 um	
Total	173.6 g
Chemex	86.8 g
Archive	86.8 g
21CT50 S6 250 um > dn > 125 um	
Total	128 g
Chemex	64 g
Archive	64 g
21CT50 S7 125 um > dn > 75 um	
Total	47.03 g
Chemex	23.515 g
Archive	23.515 g
21CT50 S8 75 um > dn > 45 um	
Total	28.47 g
Chemex	14.235 g
Archive	14.235 g
21CT50 S9 45 um > dn > 32 um	
Total	33.97 g
Chemex	16.985 g
Archive	16.985 g
21CT50 S10 32 um > dp > 20 um	
Total	3.43 g
Chemex	0 g
Archive	3.43 g
21CT50 S11 dp < 20 um	
Total	3.87 g
Chemex	0 g
Archive	3.87 g
Sum of splits	1420.07 g
% error	0.4%



Fine-grained sieving	
S5 (500 um > dp > 250 um)	
S6 (250 um > dp > 125 um)	
S7 (125 um > dp > 75 um)	
S8 (75 um > dp > 45 um)	
S9 (45 um > dp > 32 um)	
S10 (32 um > dp > 20 um)	
S11 (dp < 20 um)	

Elemental Distribution (by Concentration) vs. Particle Size

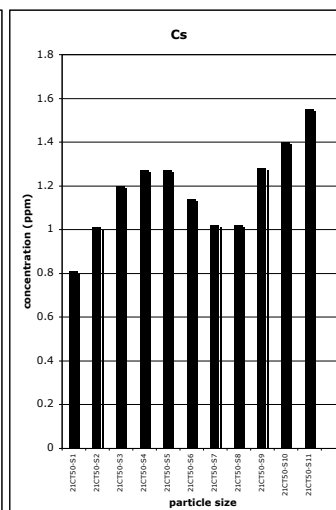
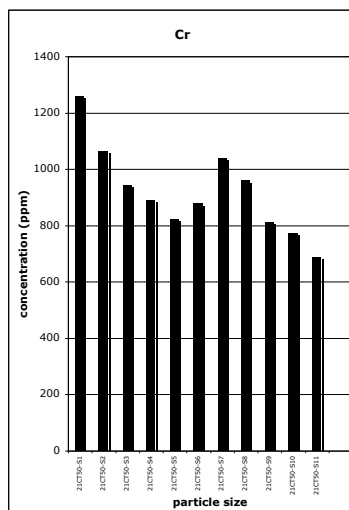
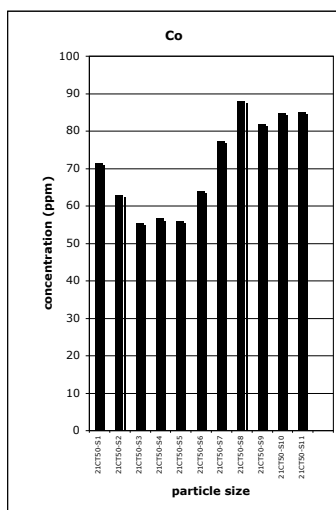
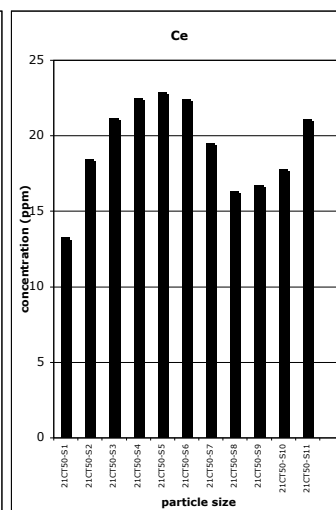
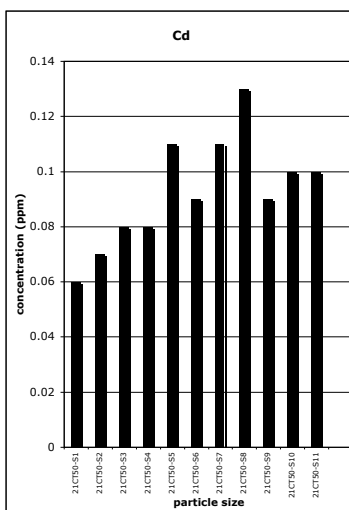
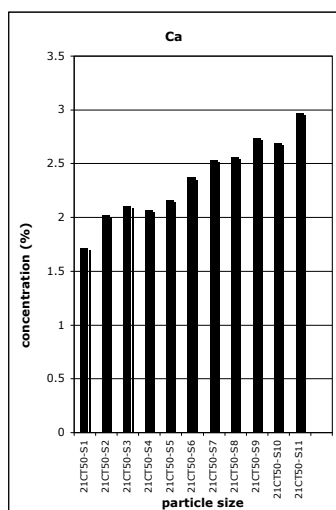
SAMPLE DESCRIPTION	WEI-21 Recvd Wt. kg	ME-MS61 Ag ppm	ME-MS61 Al %	ME-MS61 As ppm	ME-MS61 Ba ppm	ME-MS61 Be ppm	ME-MS61 Bi ppm
21CT50-S1		0.05	2.52	2.8	230	0.47	0.02
21CT50-S2		0.07	3.28	4.5	270	0.57	0.04
21CT50-S3		0.07	3.69	4.9	280	0.66	0.04
21CT50-S4		0.08	3.9	5.9	290	0.75	0.05
21CT50-S5		0.07	3.96	5.9	300	0.78	0.08
21CT50-S6		0.09	3.7	6.2	310	0.65	0.07
21CT50-S7		0.08	3.26	6.8	320	0.53	0.07
21CT50-S8		0.08	2.73	6.4	330	0.48	0.07
21CT50-S9		0.11	2.92	5.9	400	0.46	0.08
21CT50-S10		0.12	3.08	6.5	410	0.43	0.09
21CT50-S11		0.14	3.26	6.5	470	0.48	0.11



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

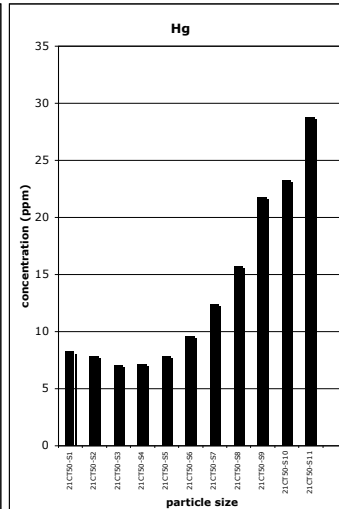
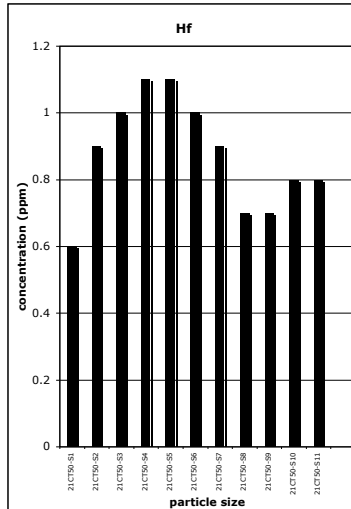
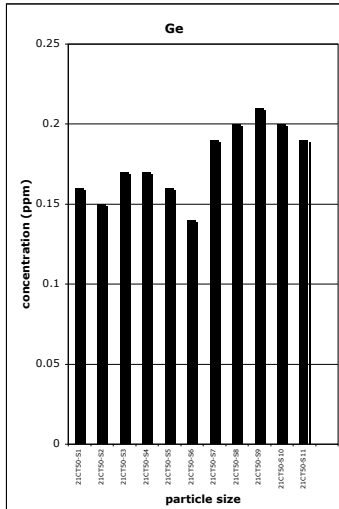
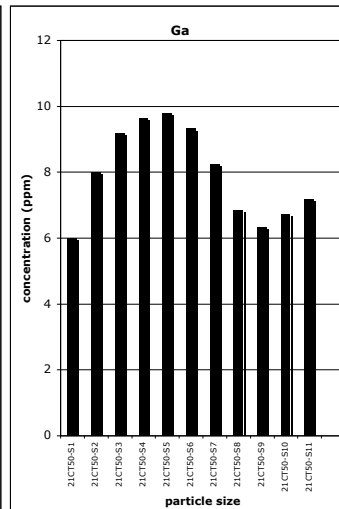
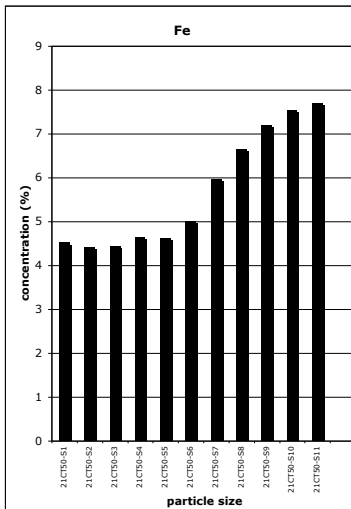
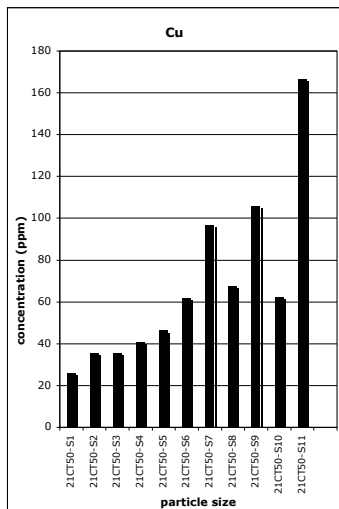
ME-MS61 Ca %	ME-MS61 Cd ppm	ME-MS61 Ce ppm	ME-MS61 Co ppm	ME-MS61 Cr ppm	ME-MS61 Cs ppm
1.72	0.06	13.25	71.5	1260	0.81
2.02	0.07	18.45	62.9	1065	1.01
2.11	0.08	21.2	55.5	943	1.2
2.07	0.08	22.5	56.6	888	1.27
2.16	0.11	22.9	56	823	1.27
2.37	0.09	22.4	63.9	877	1.14
2.53	0.11	19.5	77.4	1040	1.02
2.56	0.13	16.3	88	959	1.02
2.74	0.09	16.7	81.9	811	1.28
2.69	0.1	17.8	84.9	771	1.4
2.97	0.1	21.1	85.1	688	1.55



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

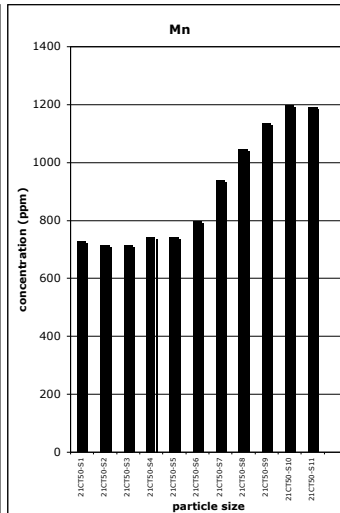
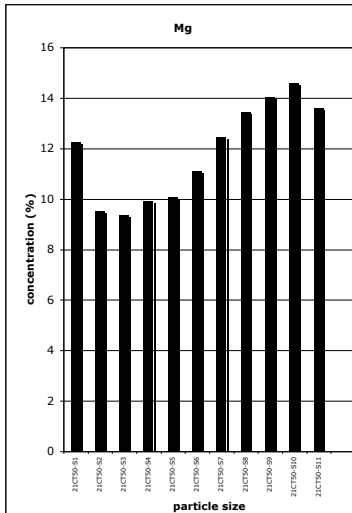
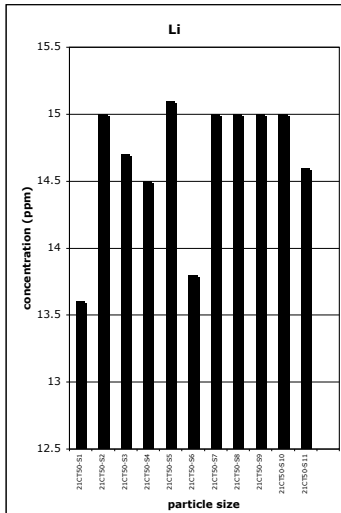
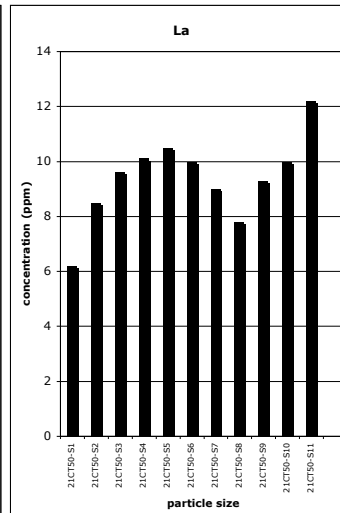
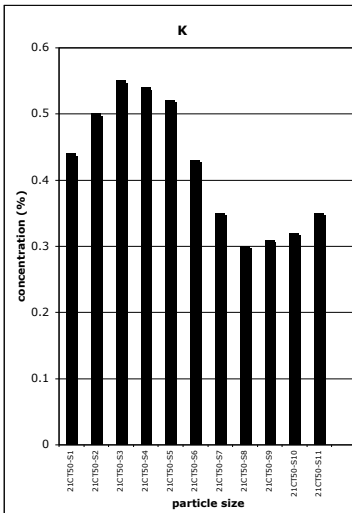
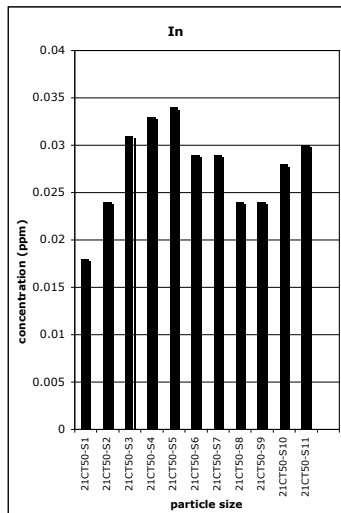
ME-MS61 Cu ppm	ME-MS61 Fe %	ME-MS61 Ga ppm	ME-MS61 Ge ppm	ME-MS61 Hf ppm	Hg-CV42 Hg ppm
25.8	4.52	5.99	0.16	0.6	8.23
35.7	4.42	8.01	0.15	0.9	7.85
35.3	4.45	9.2	0.17	1	7.07
40.7	4.64	9.64	0.17	1.1	7.15
46.2	4.63	9.81	0.16	1.1	7.83
61.9	5.01	9.32	0.14	1	9.61
96.7	5.97	8.24	0.19	0.9	12.35
67.8	6.65	6.83	0.2	0.7	15.7
106	7.19	6.34	0.21	0.7	21.8
62.3	7.53	6.72	0.2	0.8	23.3
166.5	7.7	7.19	0.19	0.8	28.8



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S8>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

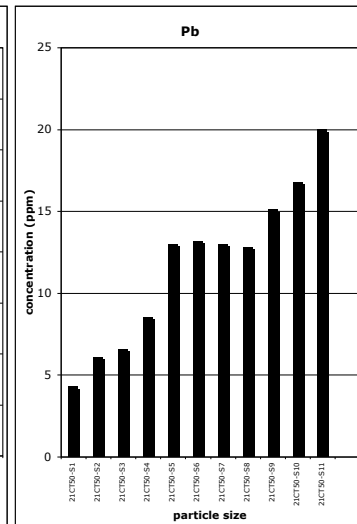
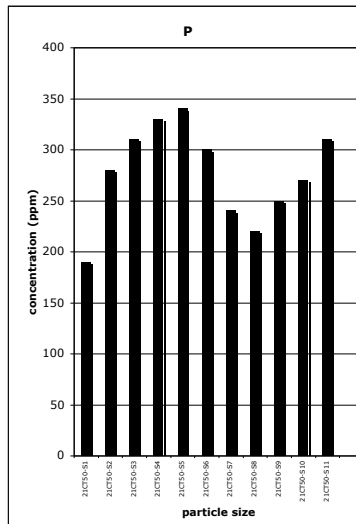
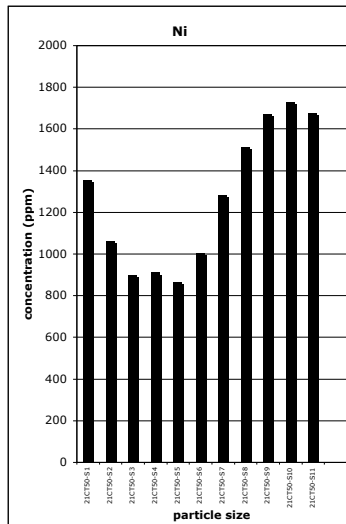
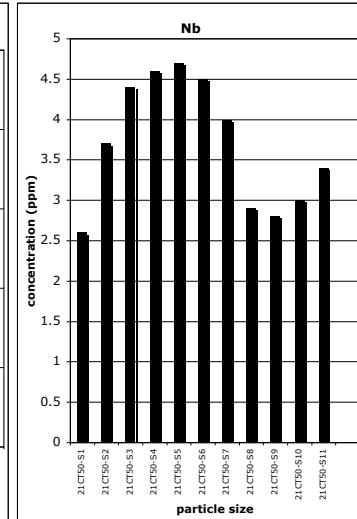
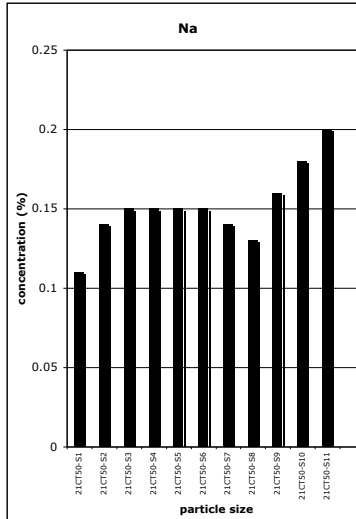
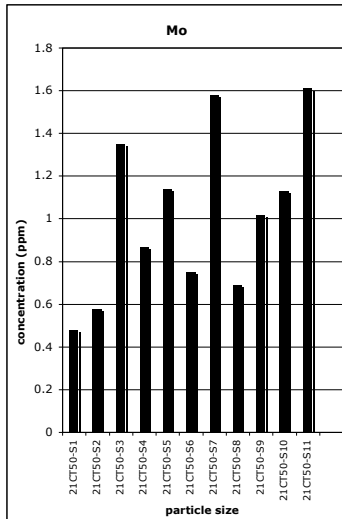
ME-MS61 In ppm	ME-MS61 K %	ME-MS61 La ppm	ME-MS61 Li ppm	ME-MS61 Mg %	ME-MS61 Mn ppm
0.018	0.44	6.2	13.6	12.25	728
0.024	0.5	8.5	15	9.53	715
0.031	0.55	9.6	14.7	9.35	715
0.033	0.54	10.1	14.5	9.93	745
0.034	0.52	10.5	15.1	10.1	745
0.029	0.43	10	13.8	11.1	797
0.029	0.35	9	15	12.45	938
0.024	0.3	7.8	15	13.45	1045
0.024	0.31	9.3	15	14.05	1135
0.028	0.32	10	15	14.6	1200
0.03	0.35	12.2	14.6	13.6	1190



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S6>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S5>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

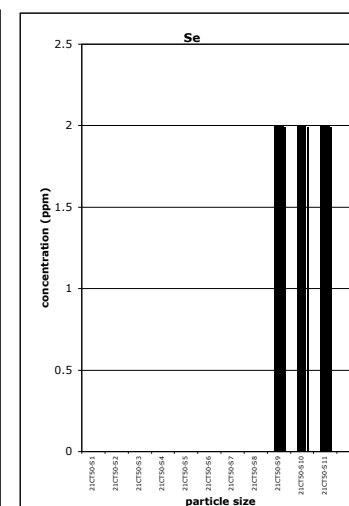
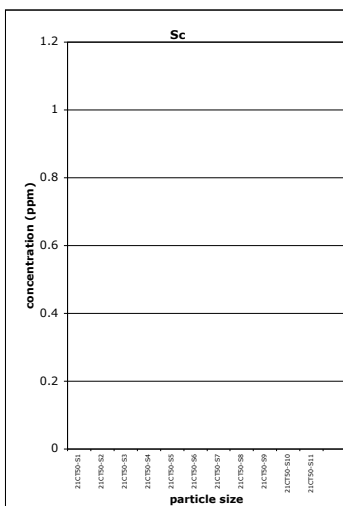
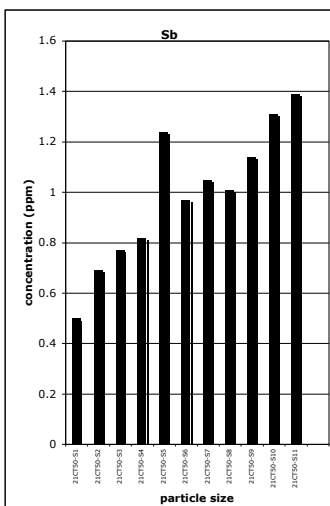
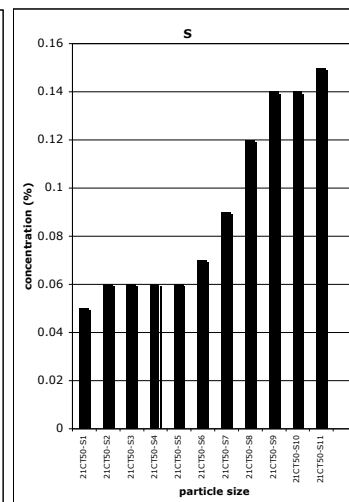
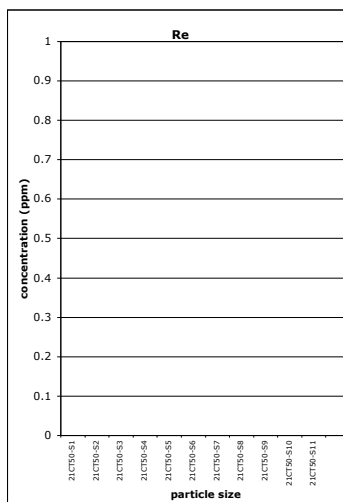
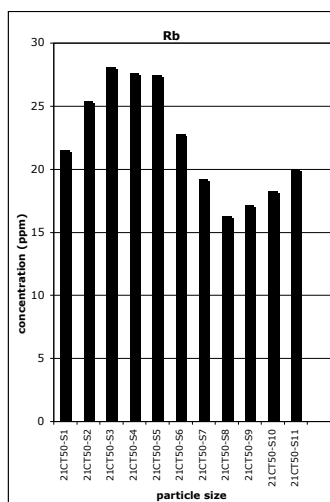
ME-MS61 Mo ppm	ME-MS61 Na %	ME-MS61 Nb ppm	ME-MS61 Ni ppm	ME-MS61 P ppm	ME-MS61 Pb ppm
0.48	0.11	2.6	1355	190	4.3
0.58	0.14	3.7	1065	280	6.1
1.35	0.15	4.4	898	310	6.6
0.87	0.15	4.6	911	330	8.5
1.14	0.15	4.7	868	340	13
0.75	0.15	4.5	1005	300	13.2
1.58	0.14	4	1285	240	13
0.69	0.13	2.9	1515	220	12.8
1.02	0.16	2.8	1670	250	15.1
1.13	0.18	3	1730	270	16.8
1.61	0.2	3.4	1675	310	20



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

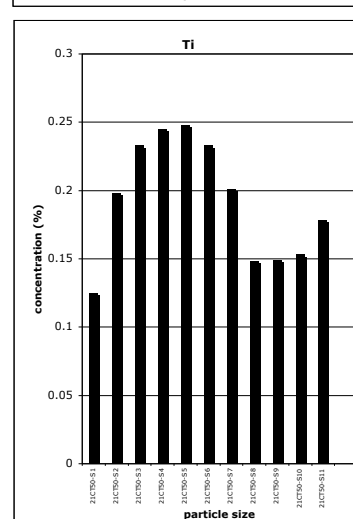
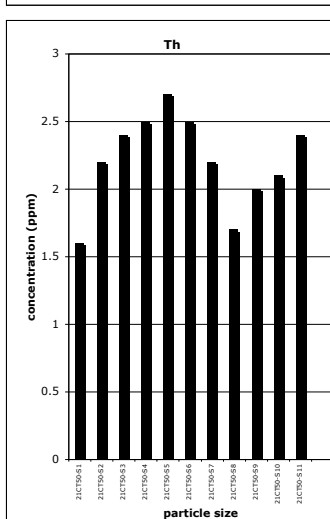
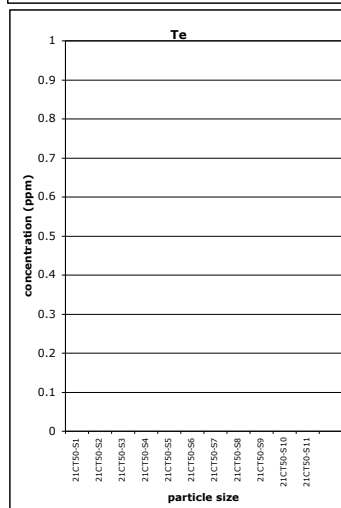
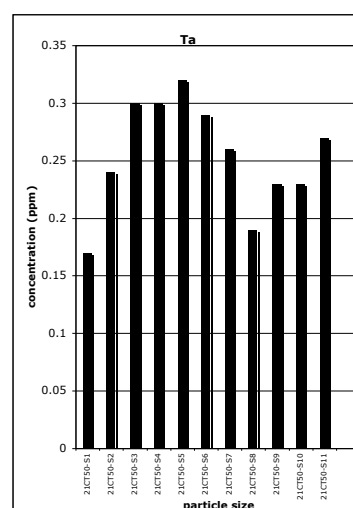
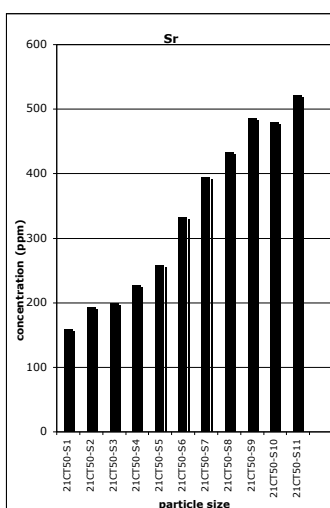
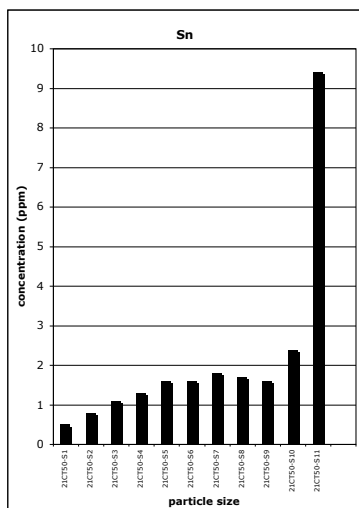
ME-MS61 Rb ppm	ME-MS61 Re ppm	ME-MS61 S %	ME-MS61 Sb ppm	ME-MS61 Sc ppm	ME-MS61 Se ppm
21.5	<0.002	0.05	0.5		<1
25.4	<0.002	0.06	0.69		<1
28.1	<0.002	0.06	0.77		<1
27.6	<0.002	0.06	0.82		<1
27.5	<0.002	0.06	1.24		<1
22.8	<0.002	0.07	0.97		<1
19.2	<0.002	0.09	1.05		<1
16.3	<0.002	0.12	1.01		<1
17.2	<0.002	0.14	1.14		2
18.3	<0.002	0.14	1.31		2
20	<0.002	0.15	1.39		2



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

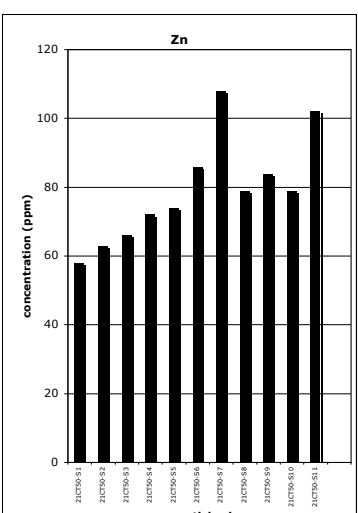
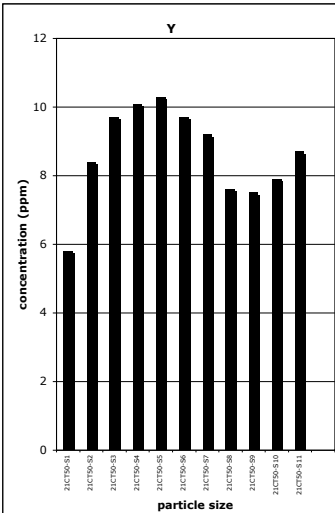
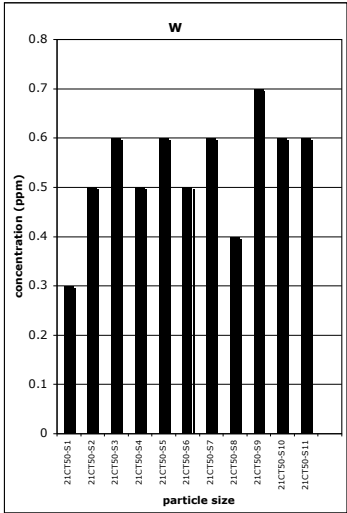
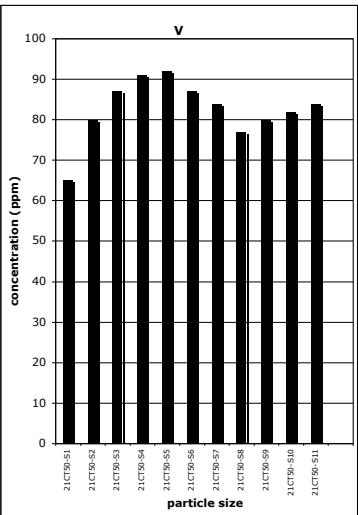
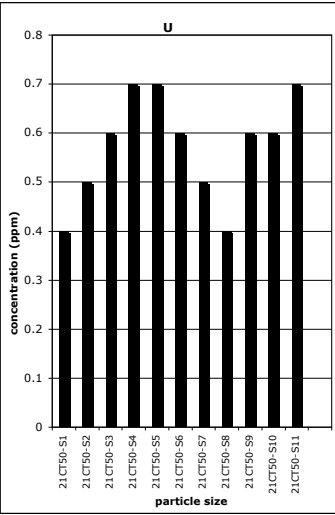
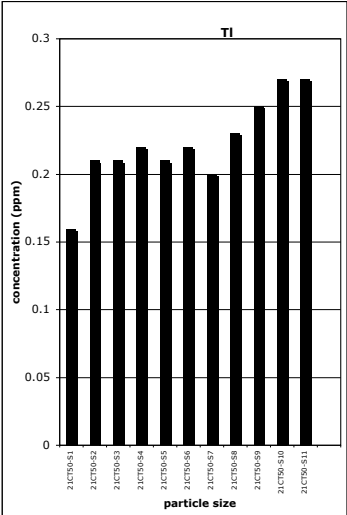
ME-MS61 Sn ppm	ME-MS61 Sr ppm	ME-MS61 Ta ppm	ME-MS61 Te ppm	ME-MS61 Th ppm	ME-MS61 Ti %
0.5	158.5	0.17	<0.05	1.6	0.125
0.8	193.5	0.24	<0.05	2.2	0.198
1.1	200	0.3	<0.05	2.4	0.233
1.3	227	0.3	<0.05	2.5	0.245
1.6	257	0.32	<0.05	2.7	0.248
1.6	333	0.29	<0.05	2.5	0.233
1.8	394	0.26	<0.05	2.2	0.201
1.7	433	0.19	<0.05	1.7	0.148
1.6	486	0.23	<0.05	2	0.149
2.4	480	0.23	<0.05	2.1	0.153
9.4	521	0.27	<0.05	2.4	0.178



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

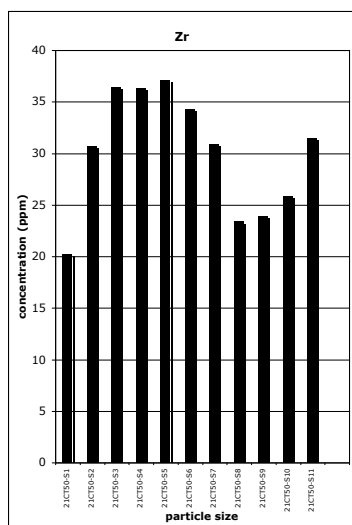
ME-MS61 Ti ppm	ME-MS61 U ppm	ME-MS61 V ppm	ME-MS61 W ppm	ME-MS61 Y ppm	ME-MS61 Zn ppm
0.16	0.4	65	0.3	5.8	58
0.21	0.5	80	0.5	8.4	63
0.21	0.6	87	0.6	9.7	66
0.22	0.7	91	0.5	10.1	72
0.21	0.7	92	0.6	10.3	74
0.22	0.6	87	0.5	9.7	86
0.2	0.5	84	0.6	9.2	108
0.23	0.4	77	0.4	7.6	79
0.25	0.6	80	0.7	7.5	84
0.27	0.6	82	0.6	7.9	79
0.27	0.7	84	0.6	8.7	102



S1> 2830 um 2830 um>S2>1700 um 1700 um>S3>1000 um	1000 um>S4>500 um 500 um>S5>250 um 250 um>S6>125 um	125 um>S7>75 um 75 um>S8>45 um 45 um>S9>32 um	32 um>S10>20 um 20 um>S11
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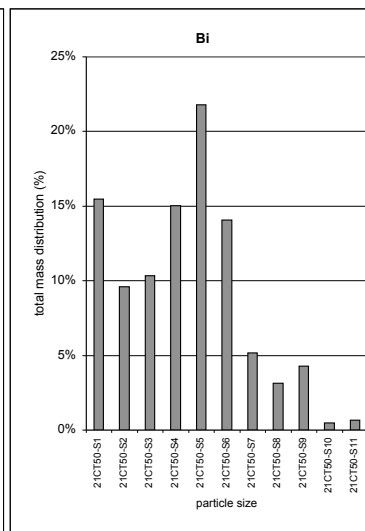
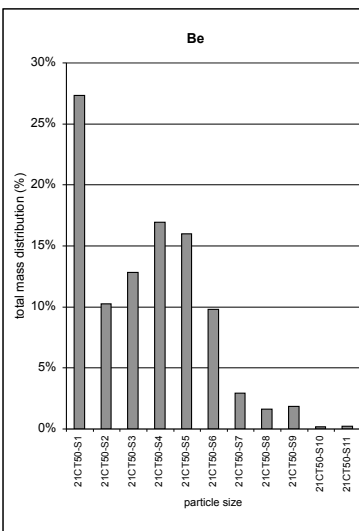
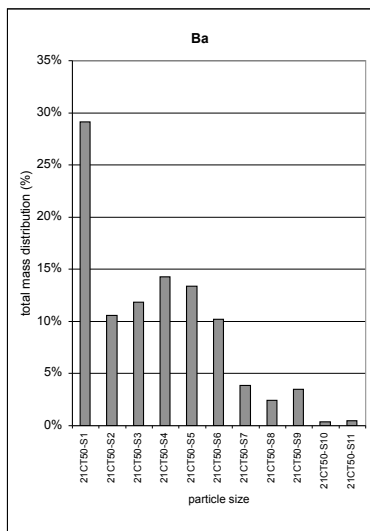
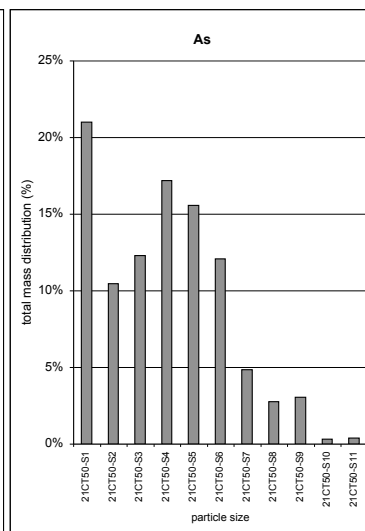
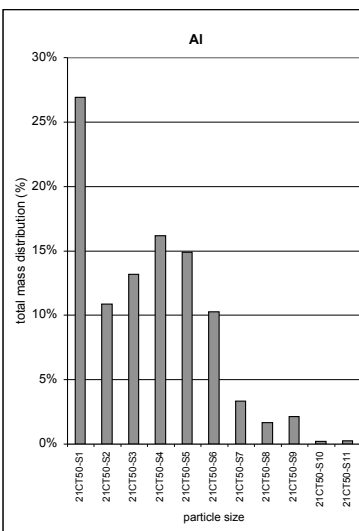
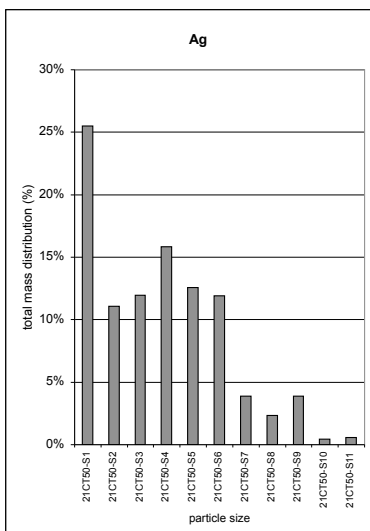
Elemental Distribution (by Concentration) vs. Particle Size

ME-MS61
Zr
ppm
20.2
30.7
36.4
36.3
37.1
34.3
30.9
23.4
23.9
25.8
31.5



Elemental Distribution (by Mass %) vs. Particle Size

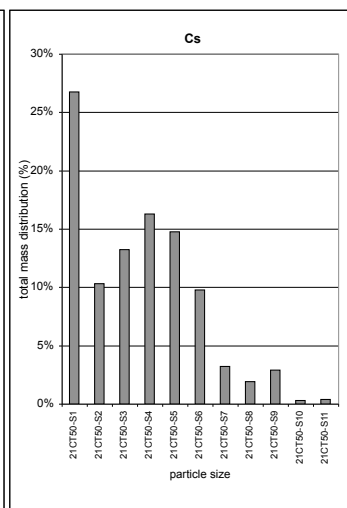
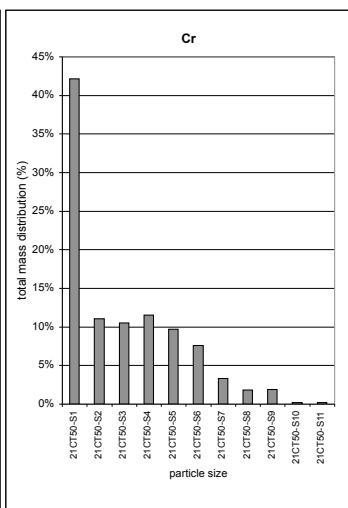
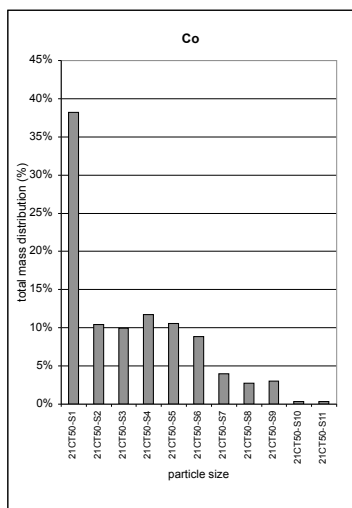
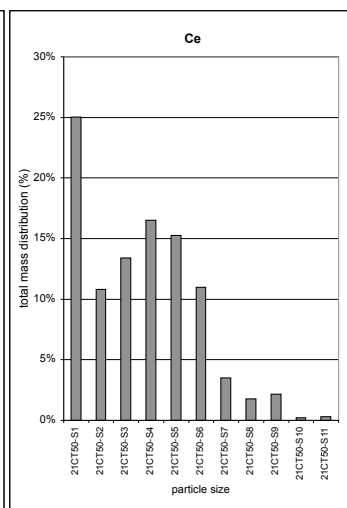
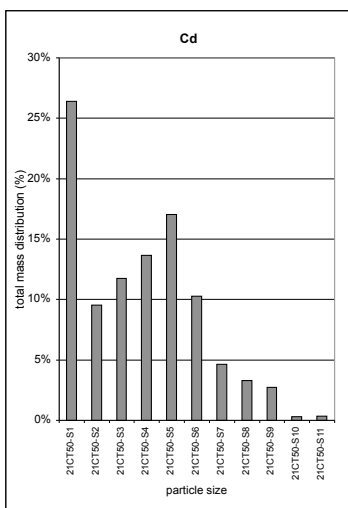
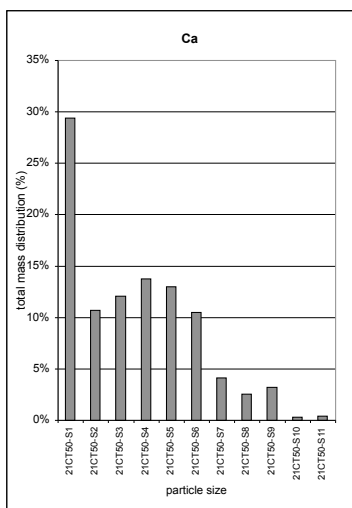
TOTAL MASS (mg)		0.10	46117.54	6.57	389.24	0.85	0.06
BULK CONC (ppm)		0.07	32608.03	4.65	275.22	0.60	0.05
SAMPLE DESCRIPTION	Recvd Wt.	Ag %	Al %	As %	Ba %	Be %	Bi %
21CT50-S1	-	26%	27%	21%	29%	27%	15%
21CT50-S2	-	11%	11%	10%	11%	10%	10%
21CT50-S3	-	12%	13%	12%	12%	13%	10%
21CT50-S4	-	16%	16%	17%	14%	17%	15%
21CT50-S5	-	13%	15%	16%	13%	16%	22%
21CT50-S6	-	12%	10%	12%	10%	10%	14%
21CT50-S7	-	4%	3%	5%	4%	3%	5%
21CT50-S8	-	2%	2%	3%	2%	2%	3%
21CT50-S9	-	4%	2%	3%	3%	2%	4%
21CT50-S10	-	0%	0%	0%	0%	0%	0%
21CT50-S11	-	1%	0%	0%	0%	0%	1%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

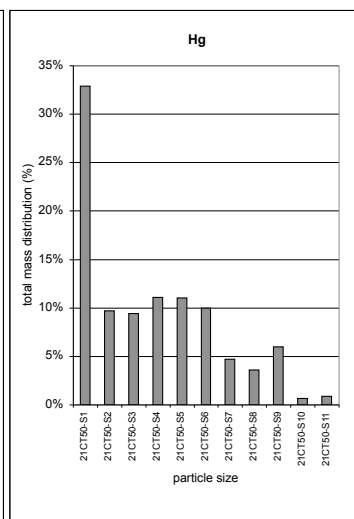
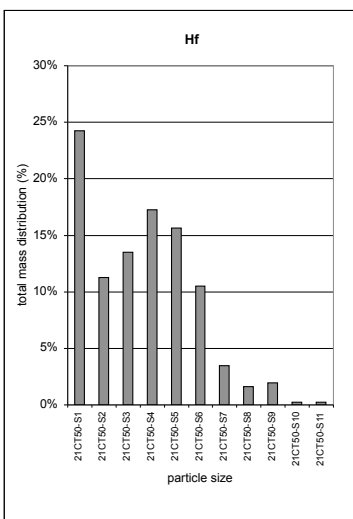
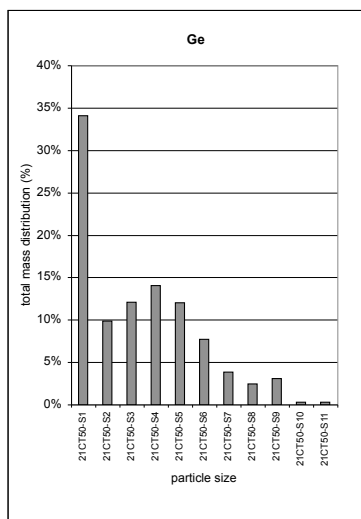
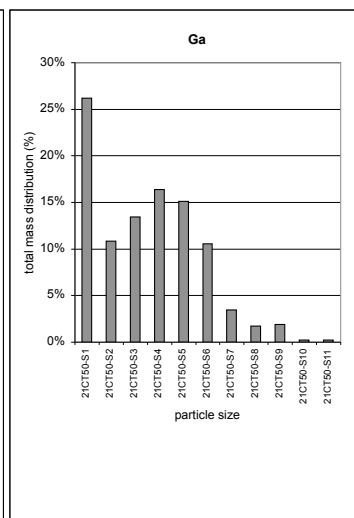
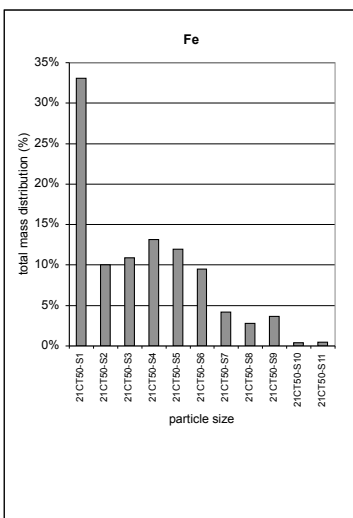
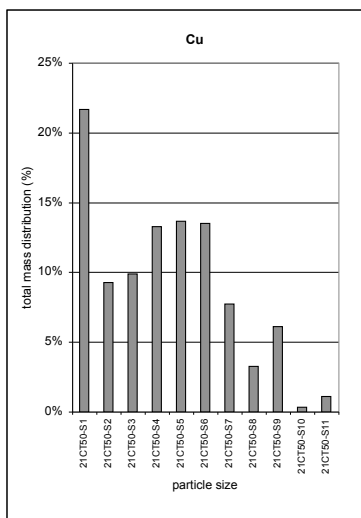
28840.00	0.11	26.08	92.27	1473.12	1.49
20391.71	0.08	18.44	65.24	1041.59	1.05
Ca	Cd	Ce	Co	Cr	Cs
%	%	%	%	%	%
29%	26%	25%	38%	42%	27%
11%	10%	11%	10%	11%	10%
12%	12%	13%	10%	11%	13%
14%	14%	17%	12%	12%	16%
13%	17%	15%	11%	10%	15%
11%	10%	11%	9%	8%	10%
4%	5%	4%	4%	3%	3%
3%	3%	2%	3%	2%	2%
3%	3%	2%	3%	2%	3%
0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

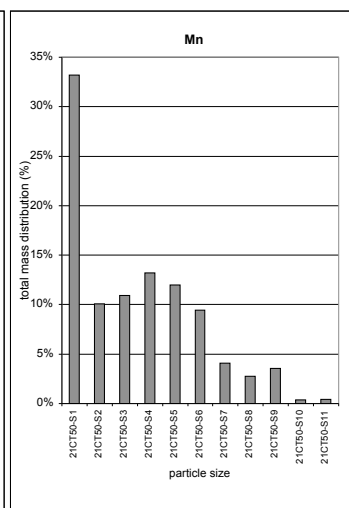
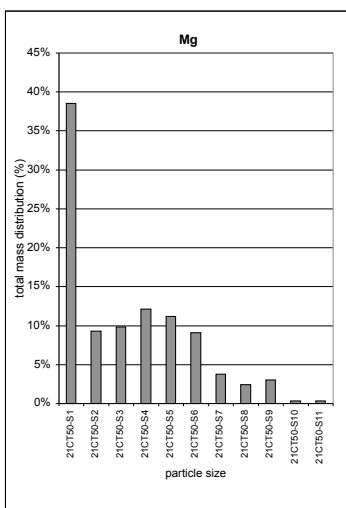
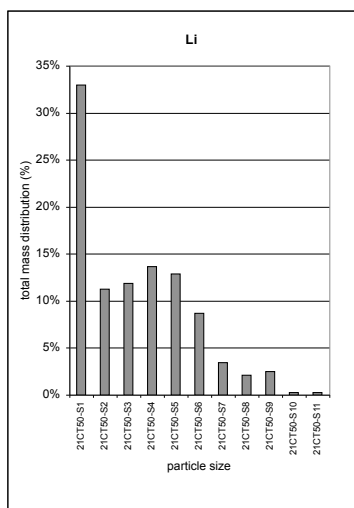
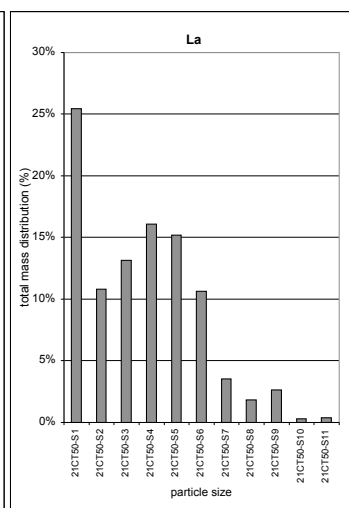
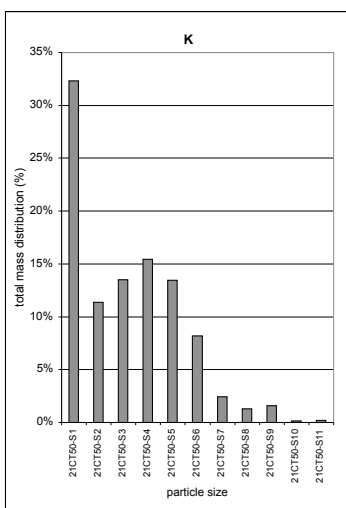
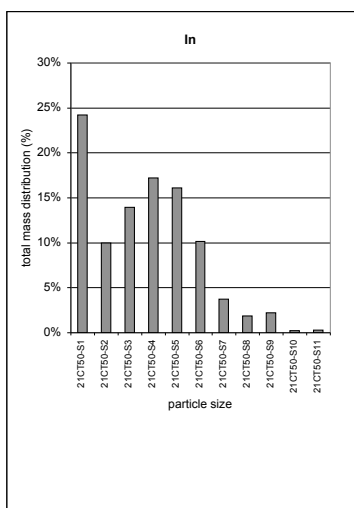
58.65	67388.60	11.28	0.23	1.22	12.34
41.47	47648.02	7.98	0.16	0.86	8.72
Cu %	Fe %	Ga %	Ge %	Hf %	Hg %
22%	33%	26%	34%	24%	33%
9%	10%	11%	10%	11%	10%
10%	11%	13%	12%	14%	9%
13%	13%	16%	14%	17%	11%
14%	12%	15%	12%	16%	11%
14%	10%	11%	8%	10%	10%
8%	4%	3%	4%	3%	5%
3%	3%	2%	2%	2%	4%
6%	4%	2%	3%	2%	6%
0%	0%	0%	0%	0%	1%
1%	0%	0%	0%	0%	1%



S1 > 2830 um 2830 um > S2 > 1700 um 1700 um > S3 > 1000 um	1000 um > S4 > 500 um 500 um > S5 > 250 um 250 um > S6 > 125 um	125 um > S7 > 75 um 75 um > S8 > 45 um 45 um > S9 > 32 um	32 um > S10 > 20 um 20 um > S11
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Elemental Distribution (by Mass %) vs. Particle Size

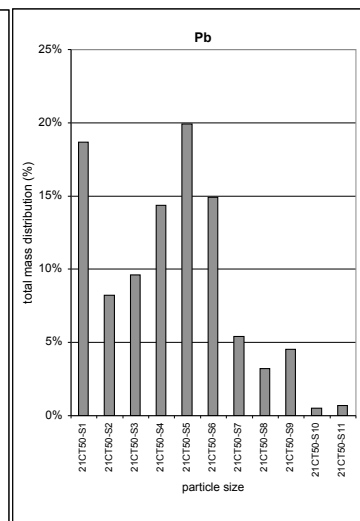
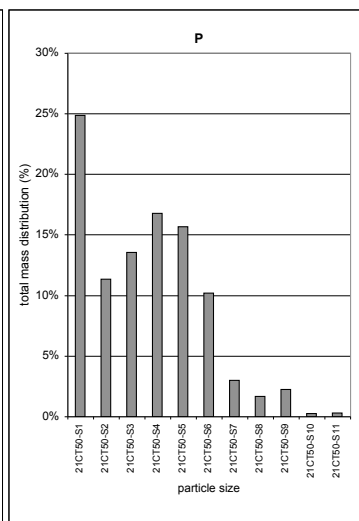
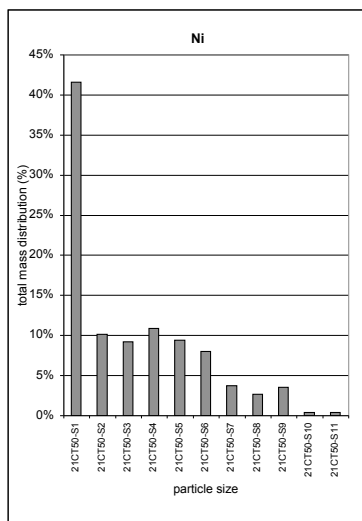
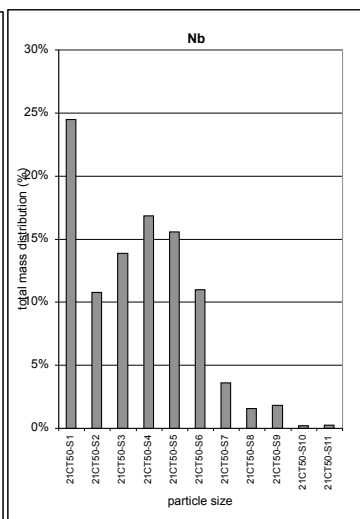
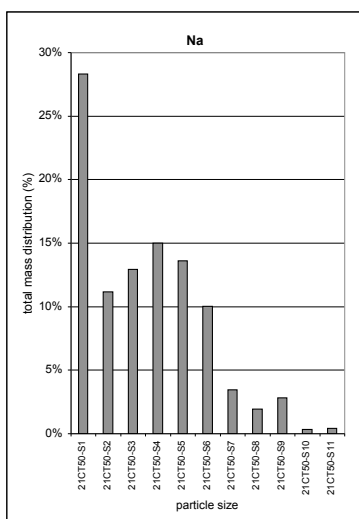
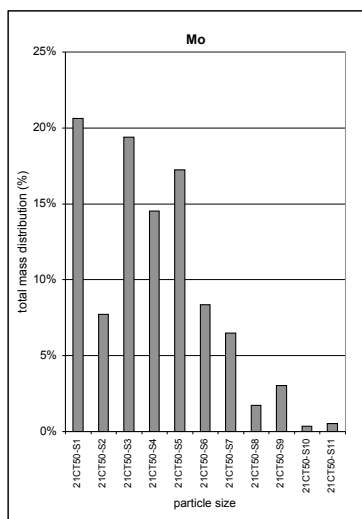
0.04	6704.74	12.01	20.33	156561.07	1080.85
0.03	4740.68	8.49	14.37	110698.62	764.23
In %	K %	La %	Li %	Mg %	Mn %
24%	32%	25%	33%	39%	33%
10%	11%	11%	11%	9%	10%
14%	14%	13%	12%	10%	11%
17%	15%	16%	14%	12%	13%
16%	13%	15%	13%	11%	12%
10%	8%	11%	9%	9%	9%
4%	2%	4%	3%	4%	4%
2%	1%	2%	2%	2%	3%
2%	2%	3%	3%	3%	4%
0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%



S1 > 2830 um 2830 um> S2 >1700 um 1700 um> S3 >1000 um	1000 um> S4 >500 um 500 um> S5 >250 um 250 um> S6 >125 um	125 um> S7 >75 um 75 um> S8 >45 um 45 um> S9 >32 um	32 um> S10 >20 um 20 um> S11
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Elemental Distribution (by Mass %) vs. Particle Size

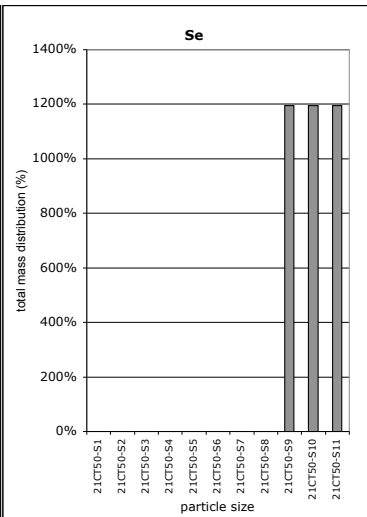
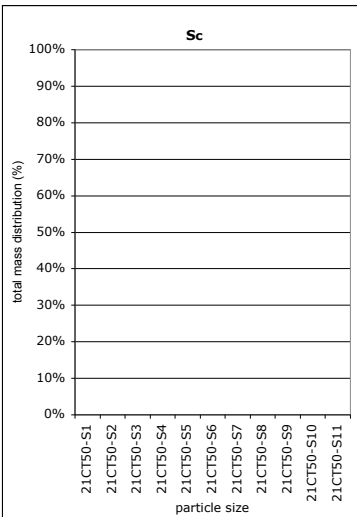
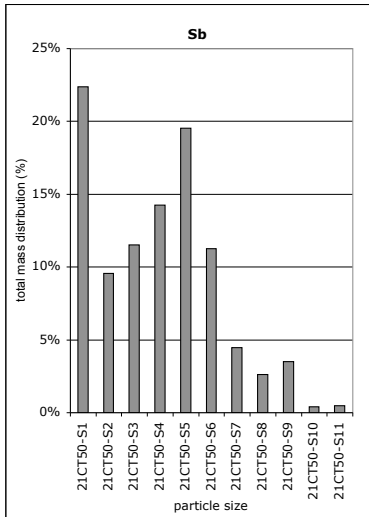
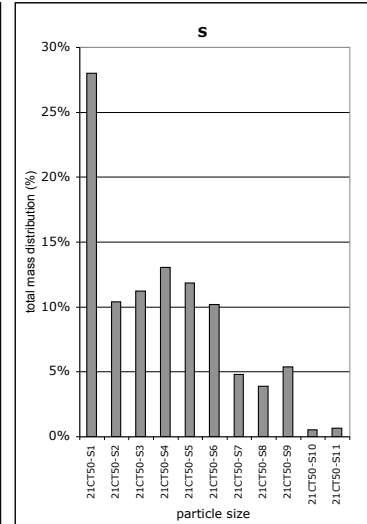
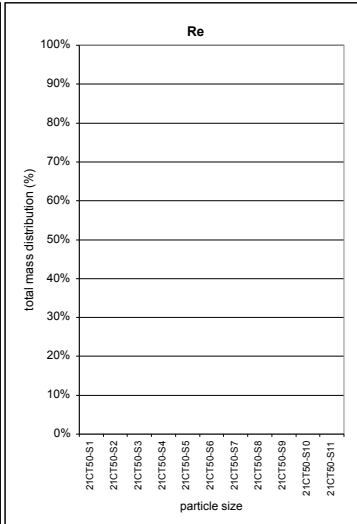
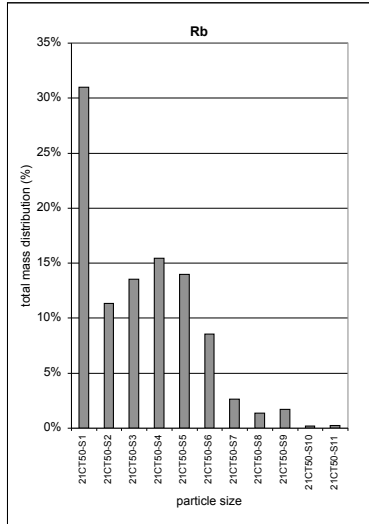
1.15	1913.68	5.23	1604.76	376.23	11.34
0.81	1353.09	3.70	1134.67	266.02	8.01
Mo	Na	Nb	Ni	P	Pb
%	%	%	%	%	%
21%	28%	24%	42%	25%	19%
8%	11%	11%	10%	11%	8%
19%	13%	14%	9%	14%	10%
15%	15%	17%	11%	17%	14%
17%	14%	16%	9%	16%	20%
8%	10%	11%	8%	10%	15%
6%	3%	4%	4%	3%	5%
2%	2%	2%	3%	2%	3%
3%	3%	2%	4%	2%	5%
0%	0%	0%	0%	0%	1%
1%	0%	0%	0%	0%	1%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

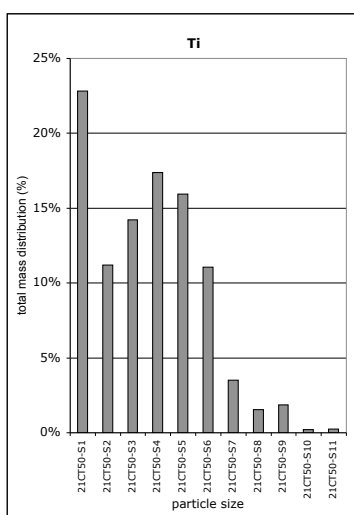
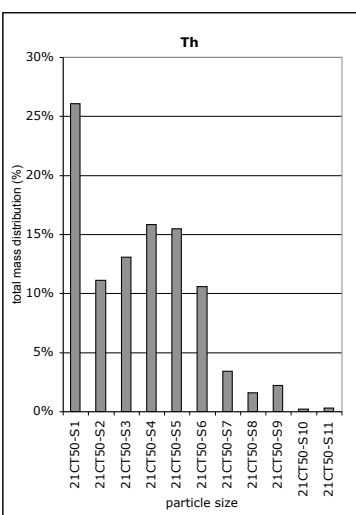
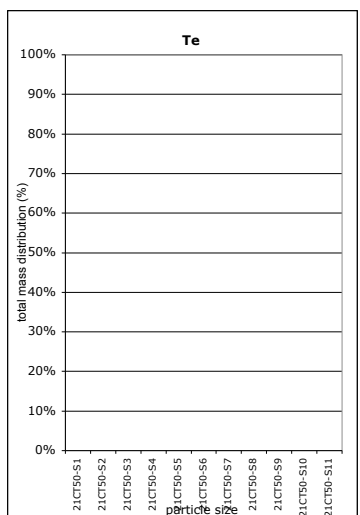
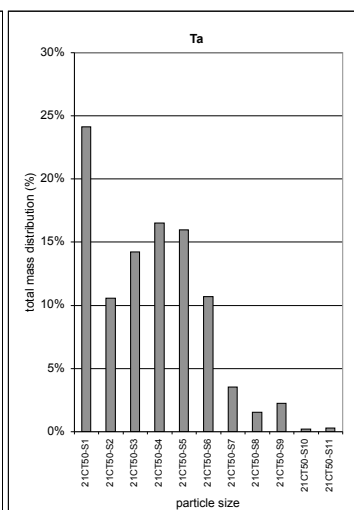
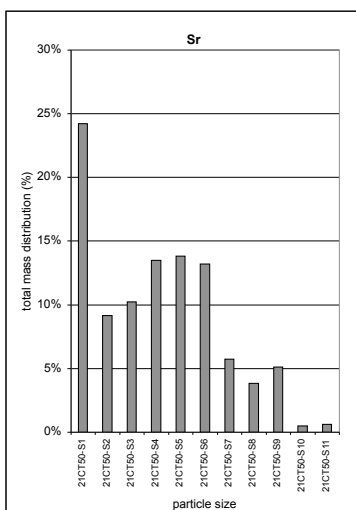
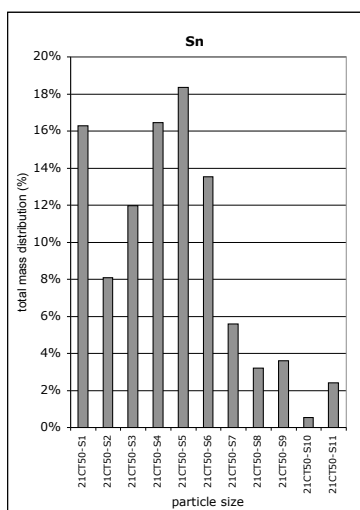
34.17	0.00	880.16	1.10	0.00	0.08
24.16	0.00	622.33	0.78	0.00	0.06
Rb	Re	S	Sb	Sc	Se
%	%	%	%	%	%
31%	#DIV/0!	28%	22%	#DIV/0!	0%
11%	#DIV/0!	10%	10%	#DIV/0!	0%
14%	#DIV/0!	11%	12%	#DIV/0!	0%
15%	#DIV/0!	13%	14%	#DIV/0!	0%
14%	#DIV/0!	12%	20%	#DIV/0!	0%
9%	#DIV/0!	10%	11%	#DIV/0!	0%
3%	#DIV/0!	5%	4%	#DIV/0!	0%
1%	#DIV/0!	4%	3%	#DIV/0!	0%
2%	#DIV/0!	5%	4%	#DIV/0!	1194%
0%	#DIV/0!	1%	0%	#DIV/0!	1194%
0%	#DIV/0!	1%	0%	#DIV/0!	1194%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

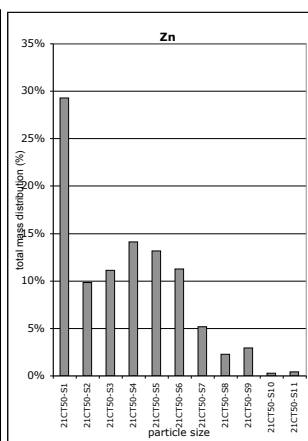
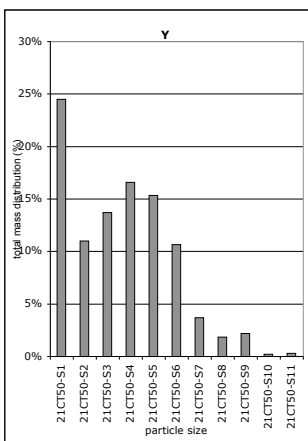
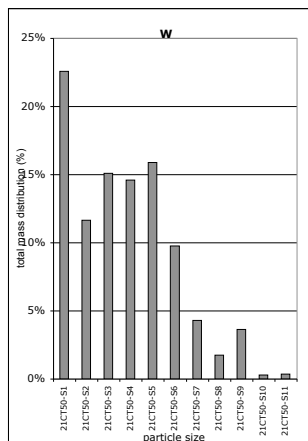
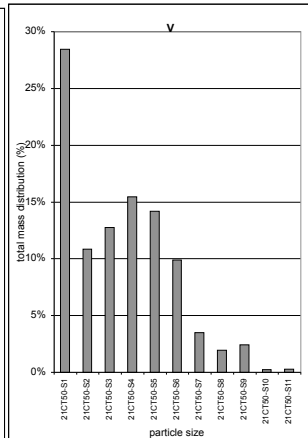
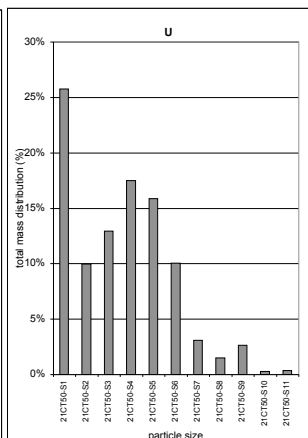
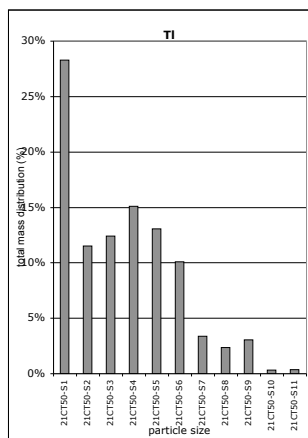
1.51	322.33	0.35	0.00	3.02	2699.45
1.07	227.91	0.25	0.00	2.14	1908.68
Sn	Sr	Ta	Te	Th	Ti
%	%	%	%	%	%
16%	24%	24%	#DIV/0!	26%	23%
8%	9%	11%	#DIV/0!	11%	11%
12%	10%	14%	#DIV/0!	13%	14%
16%	13%	17%	#DIV/0!	16%	17%
18%	14%	16%	#DIV/0!	16%	16%
14%	13%	11%	#DIV/0!	11%	11%
6%	6%	4%	#DIV/0!	3%	4%
3%	4%	2%	#DIV/0!	2%	2%
4%	5%	2%	#DIV/0!	2%	2%
1%	1%	0%	#DIV/0!	0%	0%
2%	1%	0%	#DIV/0!	0%	0%



S1> 2830 um
 2830 um>**S2**>1700 um
 1700 um>**S3**>1000 um
 1000 um>**S4**>500 um
 500 um>**S5**>250 um
 250 um>**S6**>125 um
 125 um>**S7**>75 um
 75 um>**S8**>45 um
 45 um>**S9**>32 um
 32 um>**S10**>
 20 um>**S11**

Elemental Distribution (by Mass %) vs. Particle Size

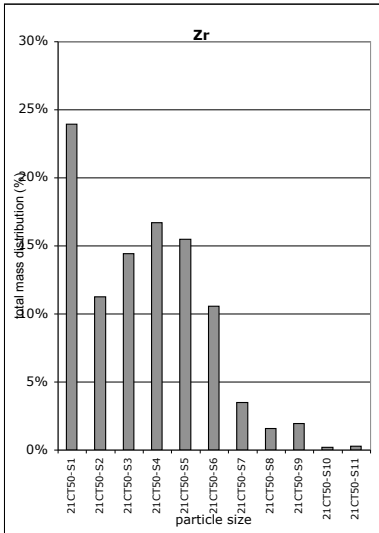
0.28	0.76	112.58	0.65	11.67	97.56
0.20	0.54	79.60	0.46	8.25	68.98
TI	U	V	W	Y	Zn
%	%	%	%	%	%
28%	26%	28%	23%	24%	29%
12%	10%	11%	12%	11%	10%
12%	13%	13%	15%	14%	11%
15%	18%	15%	15%	17%	14%
13%	16%	14%	16%	15%	13%
10%	10%	10%	10%	11%	11%
3%	3%	4%	4%	4%	5%
2%	1%	2%	2%	2%	2%
3%	3%	2%	4%	2%	3%
0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%



10>20 um 11	S1> 2830 um 2830 um>S2>1700 um 1700 um>S3>1000 um	1000 um>S4>500 um 500 um>S5>250 um 250 um>S6>125 um	125 um>S7>75 um 75 um>S8>45 um 45 um>S9>32 um	32 um>S10> 20 um>S11
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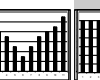
Elemental Distribution (by Mass %) vs. Particle Size

	41.56
	29.39
Zr	
%	
	24%
	11%
	14%
	17%
	15%
	11%
	3%
	2%
	2%
	0%
	0%



l0>20 um
l1

Elemental Concentration Trend Categorization

Sample								
	Direct	Inverse	Unimodal (max)	Bimodal (2 max)	Trimodal (3 max)	Reverse Unimodal (min)	Constant	Poor
21CT50		Ag Ba Bi Ca Cu Fe Hg Mg Mn Pb S Sb Sn Sr Tl	Al (S5) As (S7) Be (S5) Ce (S5) Cr (S7) Ga (S5) Hf (S4) In (S5,11) K (S3) Nb (S5) Rb (S3) Ta (S5) Th (S5) Ti (S5) V (S5) Y (S5) Zr (S5)	Cd (S5,8) Cs (S4,11) Ge (S4,9) La (S5,11) P (S5,11) U (S5,11) Zn (S7,11)		Co (S5) K (S8) Na (S8) Ni (S5)		Li Mo W

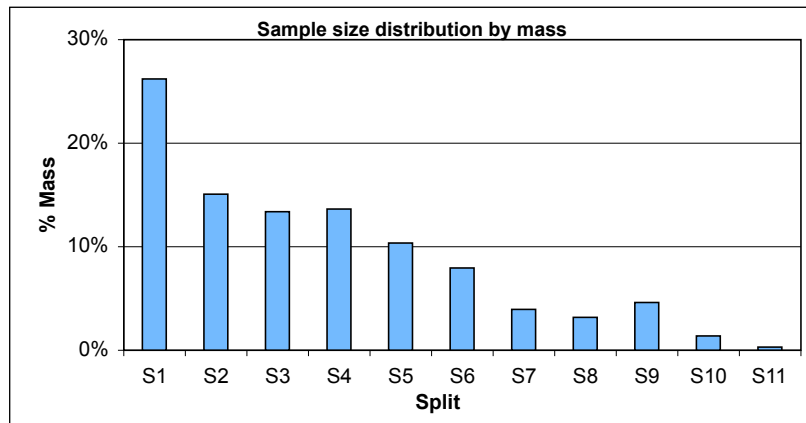
Appendix 2. Sonoma Mine calcine particle size and mass distribution and element concentrations as a function of grain size.

Sample Information	
Sample ID:	21CT8C
Sample Description:	Sonoma Mine
Date Sieved:	5/11/05
Name:	Kimo Akau

Initial Mass measurement	
Trial	Mass (g)
1	160.8
2	141.4
3	167.8
4	133.6
5	140.3
6	76.8
7	
8	
9	
10	
Total initial mass (g):	
820.7	

Particle Diameter (dp)	Split	% mass
dp >2830 um	S1	26.2%
2830 um>dp>1700 um	S2	15.1%
1700 um>dp>1000 um	S3	13.4%
1000 um>dp>500 um	S4	13.6%
500 um>dp>250 um	S5	10.4%
250 um>dp>125 um	S6	8.0%
125 um>dp>75 um	S7	3.9%
75 um>dp>45 um	S8	3.2%
45 um>dp>32 um	S9	4.6%
32 um>dp>20 um	S10	1.4%
dp<20 um	S11	0.3%

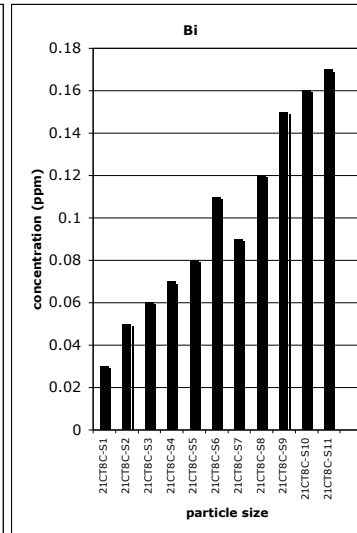
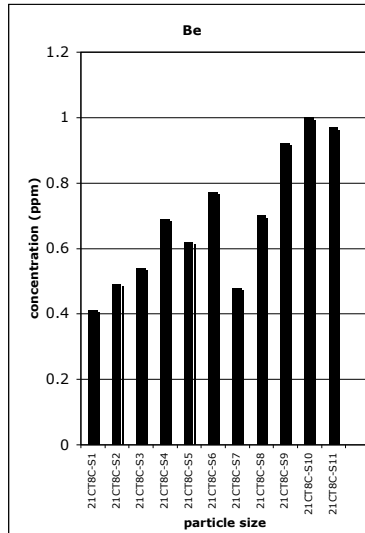
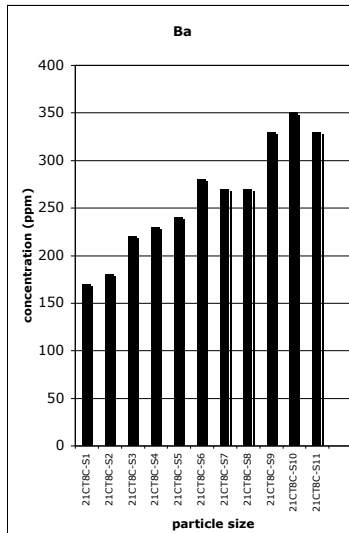
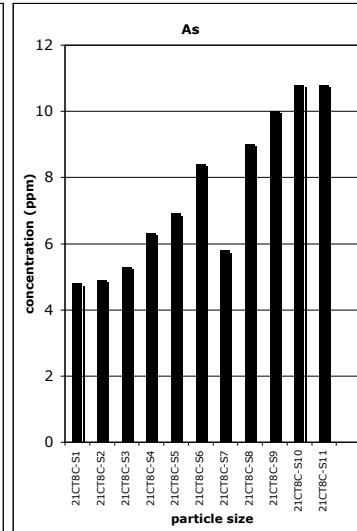
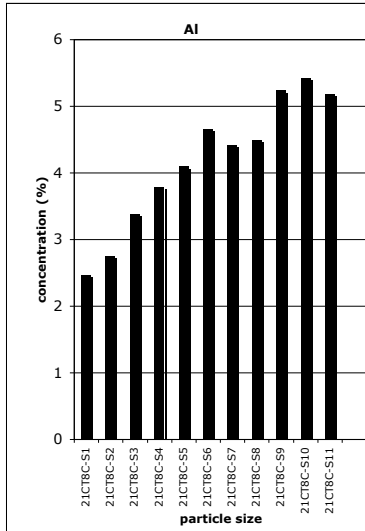
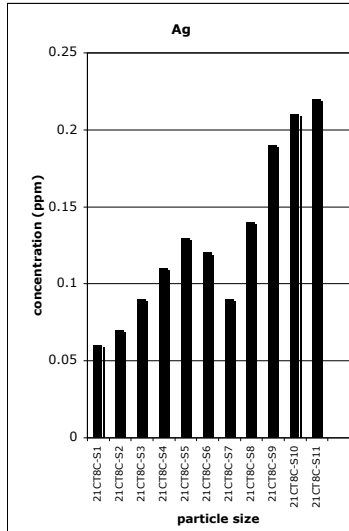
Sample split information	
21CT8C S1 dp >2830 um	21CT8C S6 250 um>dp>125 um
Total 213.2 g	Total 64.9 g
Chemex 106.6 g	Chemex 32.45 g
Archive 106.6 g	Archive 32.45 g
21CT8C S2 2830 um>dp>1700 um	21CT8C S7 125 um>dp>75 um
Total 122.8 g	Total 32.02 g
Chemex 61.4 g	Chemex 16.01 g
Archive 61.4 g	Archive 16.01 g
21CT8C S3 1700 um>dp>1000 um	21CT8C S8 75 um>dp>45 um
Total 109 g	Total 25.82 g
Chemex 54.5 g	Chemex 12.91 g
Archive 54.5 g	Archive 12.91 g
21CT8C S4 1000 um>dp>500 um	21CT8C S9 45 um>dp>32 um
Total 110.9 g	Total 37.42 g
Chemex 55.45 g	Chemex 18.71 g
Archive 55.45 g	Archive 18.71 g
21CT8C S5 500 um>dp>250 um	21CT8C S10 32 um>dp>20 um
Total 84.3 g	Total 11.12 g
Chemex 42.15 g	Chemex 11.12 g
Archive 42.15 g	Archive 11.12 g
Sum of splits 814.08 g	21CT8C S11 dp<20 um
% error 0.8%	Total 2.6 g
	Chemex g
	Archive 2.6 g



Fine-grained sieving	
S5 (500 um>dp>250 um)	
S6 (250 um>dp>125 um)	
S7 (125 um>dp>75 um)	
S8 (75 um>dp>45 um)	
S9 (45 um>dp>32 um)	
S10 (32 um>dp>20 um)	
S11 (dp<20 um)	

Elemental Distribution (by Concentration) vs. Particle Size

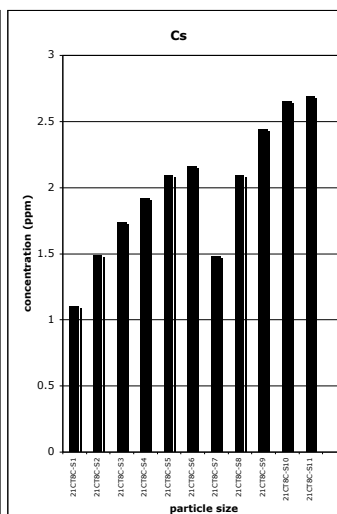
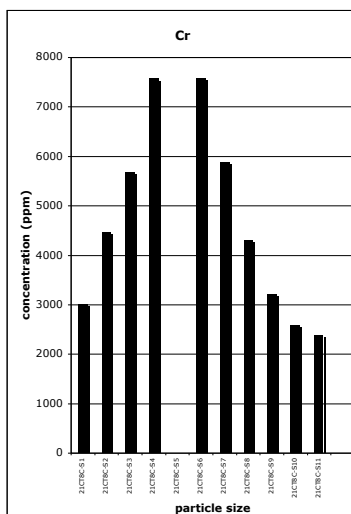
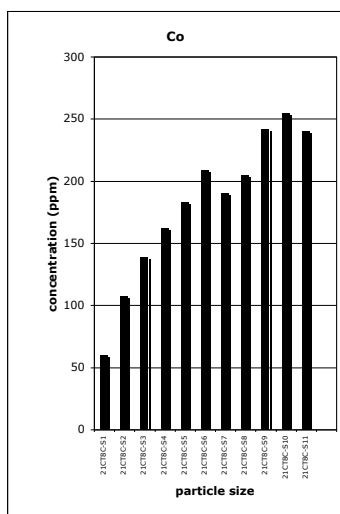
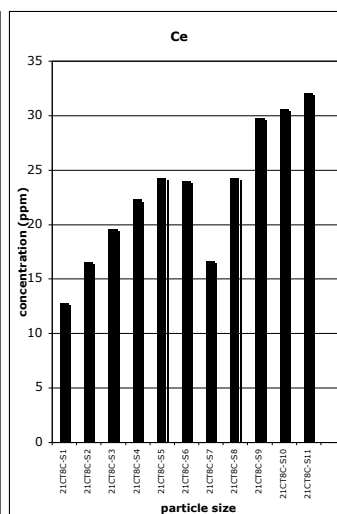
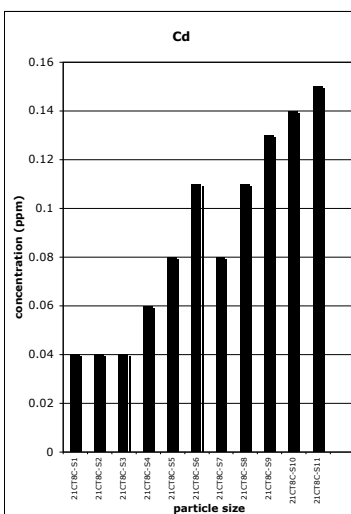
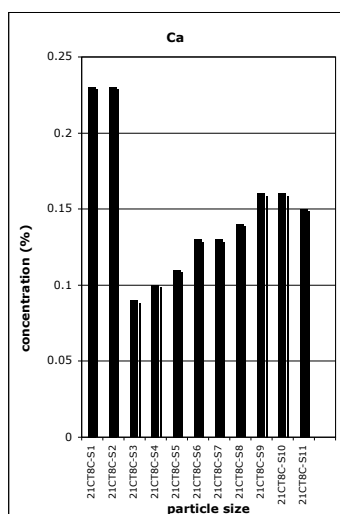
SAMPLE DESCRIPTION	WEI-21 Recvd Wt. kg	ME-MS61 Ag ppm	ME-MS61 Al %	ME-MS61 As ppm	ME-MS61 Ba ppm	ME-MS61 Be ppm	ME-MS61 Bi ppm
21CT8C-S1		0.06	2.47	4.8	170	0.41	0.03
21CT8C-S2		0.07	2.75	4.9	180	0.49	0.05
21CT8C-S3		0.09	3.39	5.3	220	0.54	0.06
21CT8C-S4		0.11	3.79	6.3	230	0.69	0.07
21CT8C-S5		0.13	4.1	6.9	240	0.62	0.08
21CT8C-S6		0.12	4.66	8.4	280	0.77	0.11
21CT8C-S7		0.09	4.42	5.8	270	0.48	0.09
21CT8C-S8		0.14	4.5	9	270	0.7	0.12
21CT8C-S9		0.19	5.24	10	330	0.92	0.15
21CT8C-S10		0.21	5.43	10.8	350	1	0.16
21CT8C-S11		0.22	5.18	10.8	330	0.97	0.17



S1> 2830 um 2830 um>S2>1700 um 1700 um>S3>1000 um	1000 um>S4>500 um 500 um>S5>250 um 250 um>S6>125 um	125 um>S7>75 um 75 um>S8>45 um 45 um>S9>32 um	32 um>S10>20 um 20 um>S11
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Elemental Distribution (by Concentration) vs. Particle Size

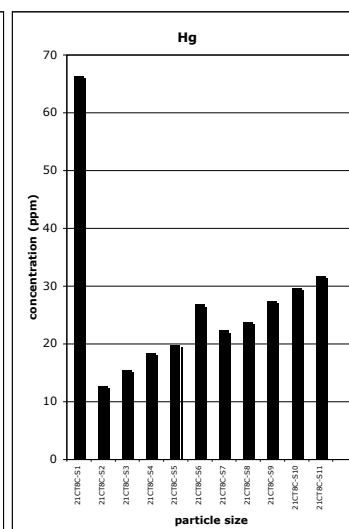
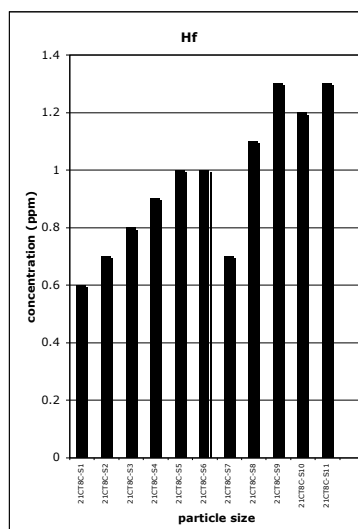
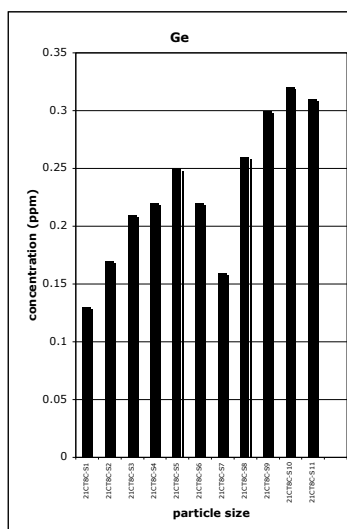
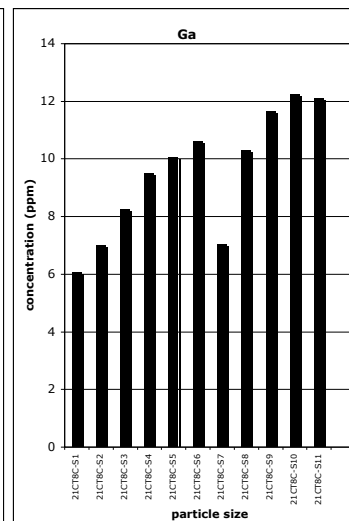
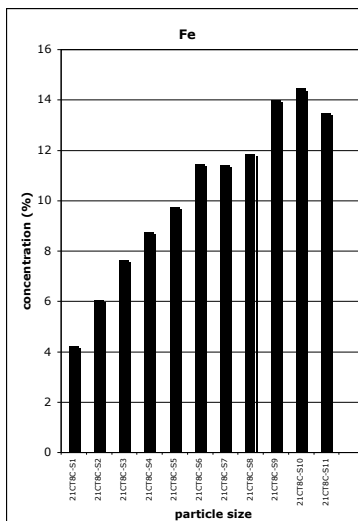
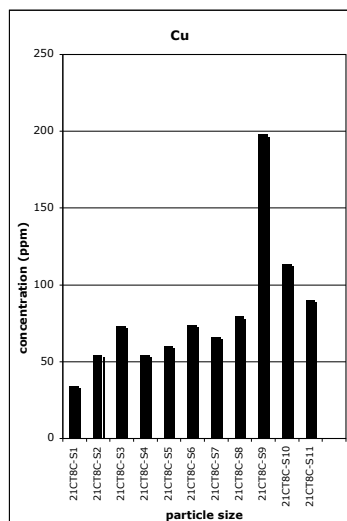
ME-MS61 Ca %	ME-MS61 Cd ppm	ME-MS61 Ce ppm	ME-MS61 Co ppm	ME-MS61 Cr ppm	ME-MS61 Cs ppm
0.23	0.04	12.8	60.2	3010	1.1
0.23	0.04	16.6	108	4470	1.49
0.09	0.04	19.65	138.5	5690	1.74
0.1	0.06	22.3	162.5	7570	1.92
0.11	0.08	24.3	183	>10000	2.09
0.13	0.11	24	209	7580	2.16
0.13	0.08	16.65	190	5890	1.48
0.14	0.11	24.3	205	4310	2.09
0.16	0.13	29.8	242	3210	2.44
0.16	0.14	30.6	255	2590	2.65
0.15	0.15	32.1	240	2380	2.69



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S6>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

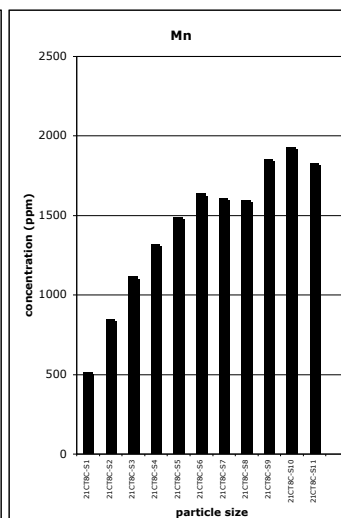
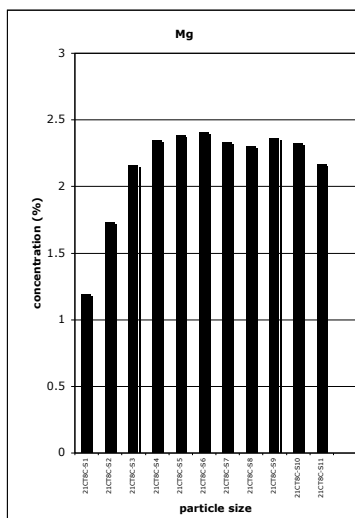
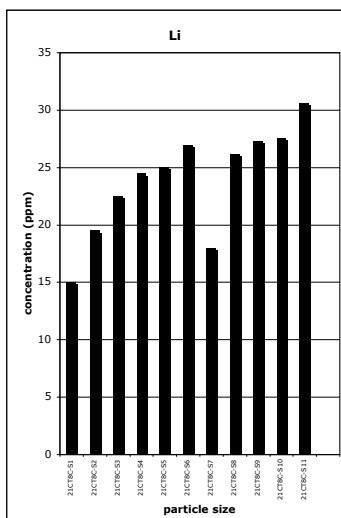
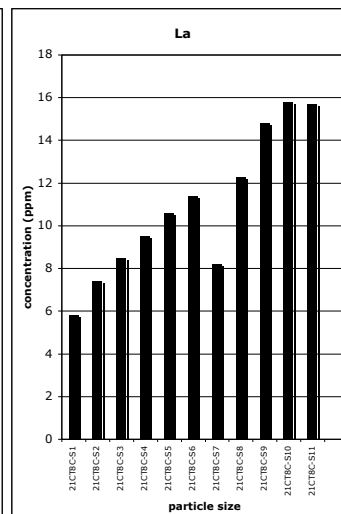
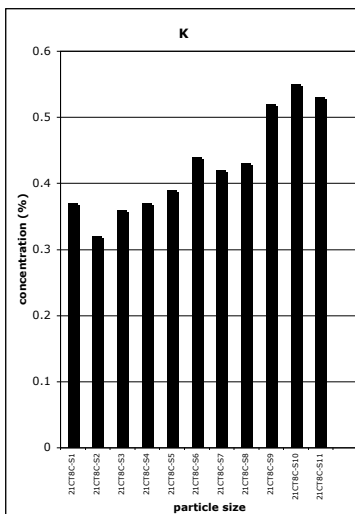
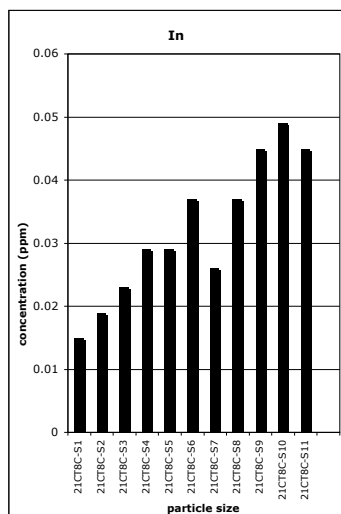
ME-MS61 Cu ppm	ME-MS61 Fe %	ME-MS61 Ga ppm	ME-MS61 Ge ppm	ME-MS61 Hf ppm	Hg-CV42 Hg ppm
34.4	4.23	6.07	0.13	0.6	66.4
54.1	6.06	7.01	0.17	0.7	12.85
73.3	7.63	8.27	0.21	0.8	15.55
54.5	8.77	9.51	0.22	0.9	18.5
60.2	9.74	10.05	0.25	1	19.85
74.1	11.45	10.6	0.22	1	26.8
66	11.4	7.03	0.16	0.7	22.3
79.6	11.85	10.3	0.26	1.1	23.8
198	14	11.65	0.3	1.3	27.4
113.5	14.45	12.25	0.32	1.2	29.6
90.2	13.5	12.1	0.31	1.3	31.8



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

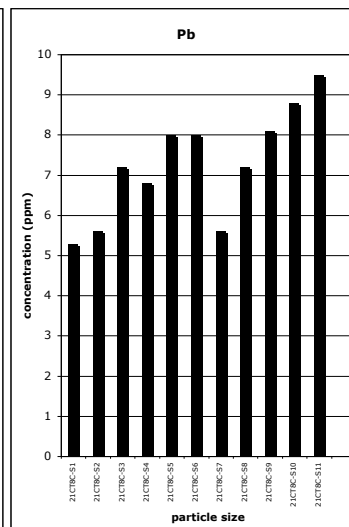
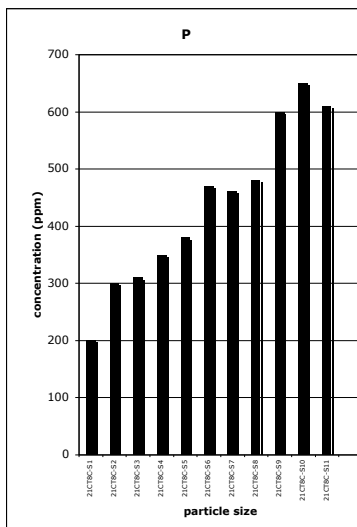
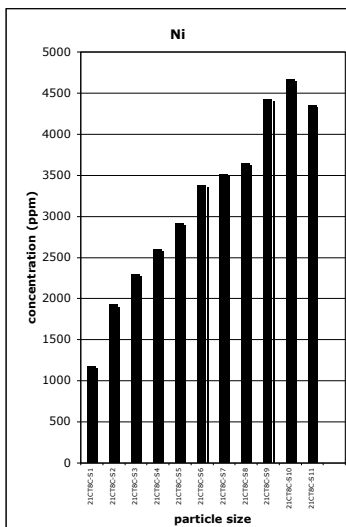
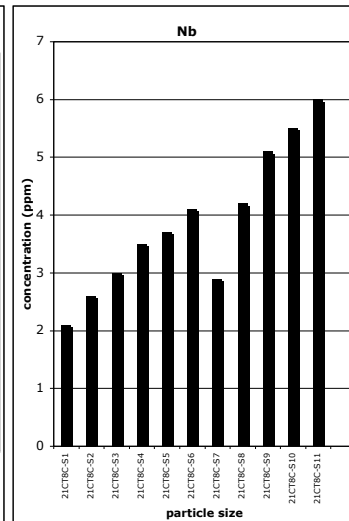
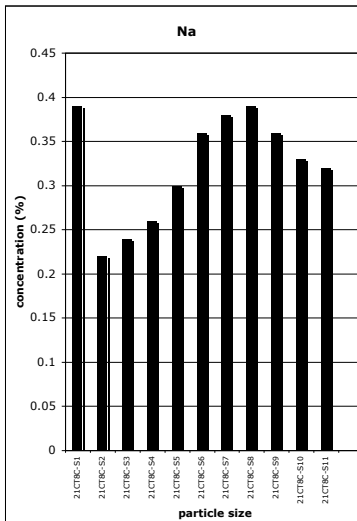
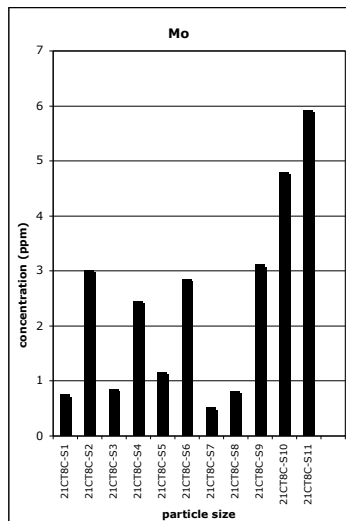
ME-MS61 In ppm	ME-MS61 K %	ME-MS61 La ppm	ME-MS61 Li ppm	ME-MS61 Mg %	ME-MS61 Mn ppm
0.015	0.37	5.8	15	1.19	515
0.019	0.32	7.4	19.5	1.73	847
0.023	0.36	8.5	22.5	2.16	1115
0.029	0.37	9.5	24.5	2.35	1320
0.029	0.39	10.6	25.1	2.38	1485
0.037	0.44	11.4	27	2.41	1635
0.026	0.42	8.2	18	2.33	1605
0.037	0.43	12.3	26.2	2.3	1595
0.045	0.52	14.8	27.3	2.36	1855
0.049	0.55	15.8	27.6	2.32	1930
0.045	0.53	15.7	30.6	2.17	1830



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

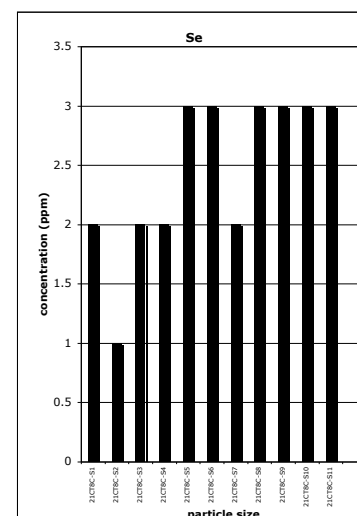
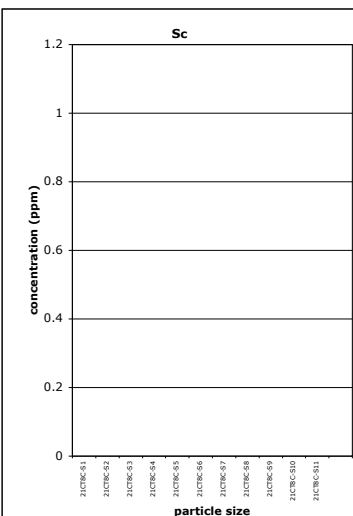
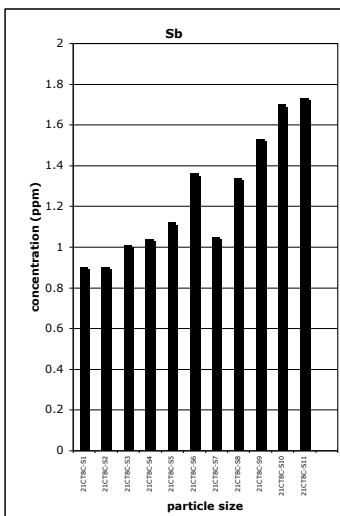
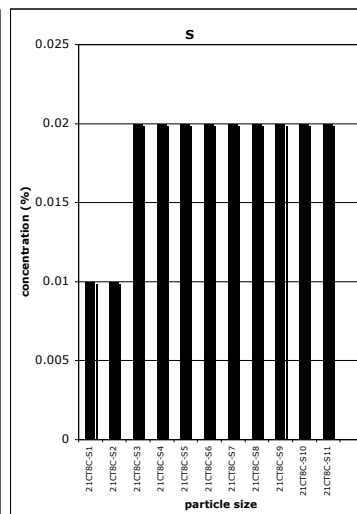
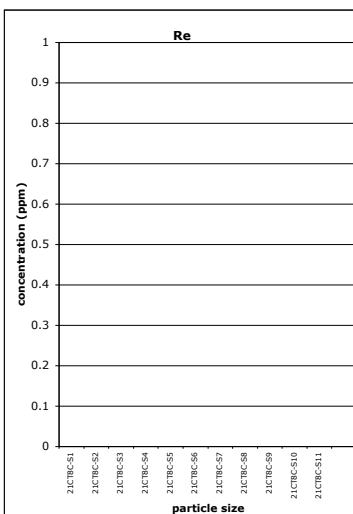
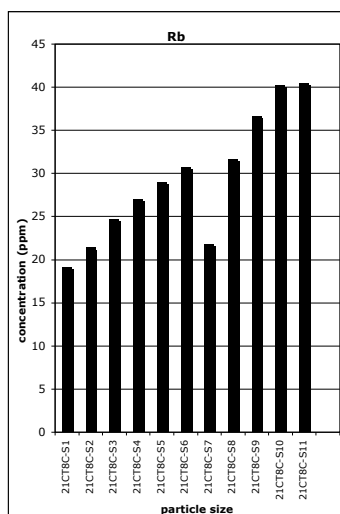
ME-MS61 Mo ppm	ME-MS61 Na %	ME-MS61 Nb ppm	ME-MS61 Ni ppm	ME-MS61 P ppm	ME-MS61 Pb ppm
0.75	0.39	2.1	1180	200	5.3
3.01	0.22	2.6	1925	300	5.6
0.85	0.24	3	2300	310	7.2
2.45	0.26	3.5	2600	350	6.8
1.16	0.3	3.7	2910	380	8
2.85	0.36	4.1	3380	470	8
0.51	0.38	2.9	3510	460	5.6
0.82	0.39	4.2	3650	480	7.2
3.11	0.36	5.1	4430	600	8.1
4.78	0.33	5.5	4670	650	8.8
5.93	0.32	6	4350	610	9.5



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

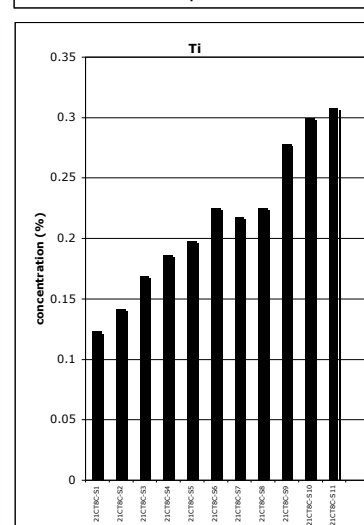
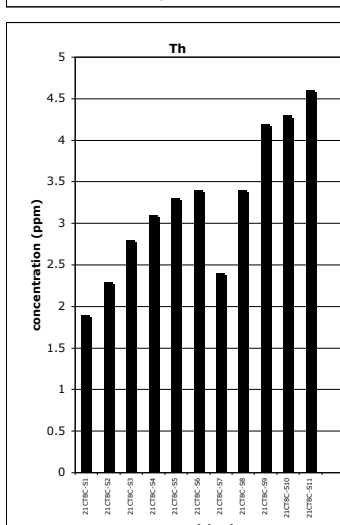
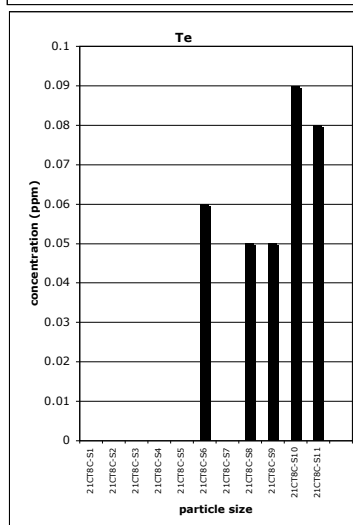
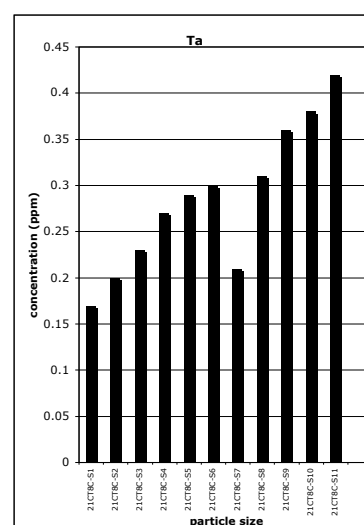
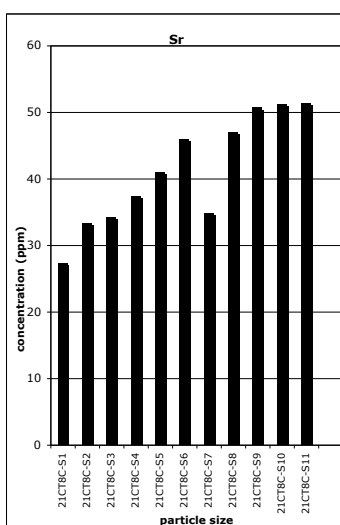
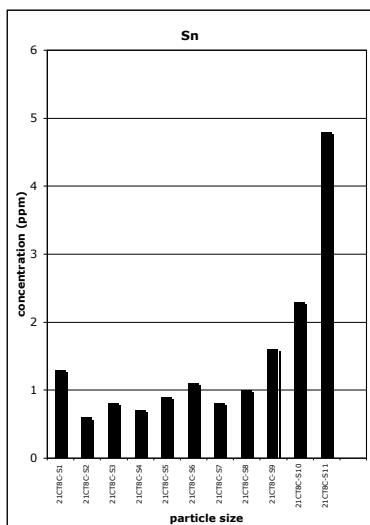
ME-MS61 Rb ppm	ME-MS61 Re ppm	ME-MS61 S %	ME-MS61 Sb ppm	ME-MS61 Sc ppm	ME-MS61 Se ppm
19.2	<0.002	0.01	0.9		2
21.4	<0.002	0.01	0.9		1
24.7	<0.002	0.02	1.01		2
27	<0.002	0.02	1.04		2
29	<0.002	0.02	1.12		3
30.7	<0.002	0.02	1.36		3
21.8	<0.002	0.02	1.05		2
31.7	<0.002	0.02	1.34		3
36.7	<0.002	0.02	1.53		3
40.2	<0.002	0.02	1.7		3
40.5	<0.002	0.02	1.73		3



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

Elemental Distribution (by Concentration) vs. Particle Size

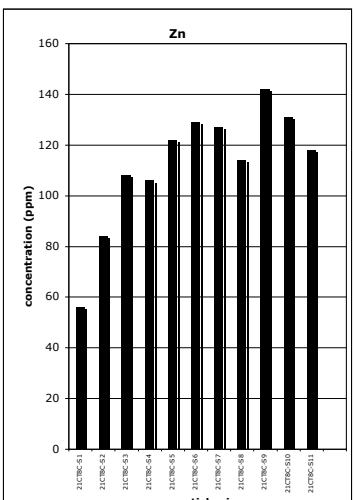
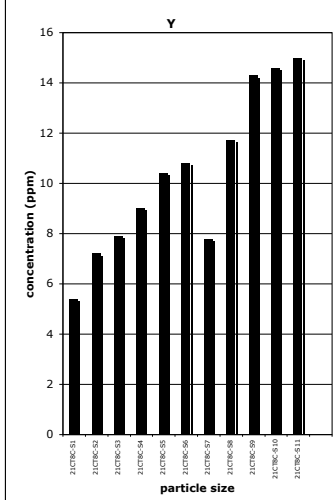
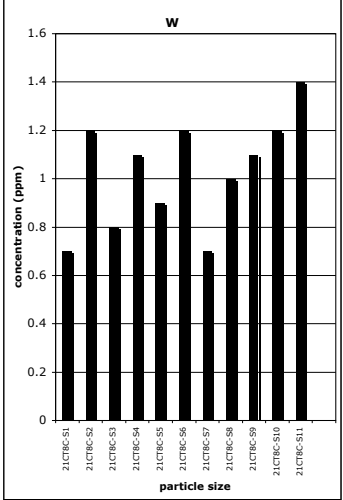
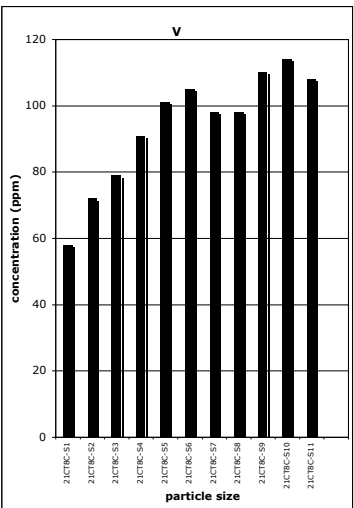
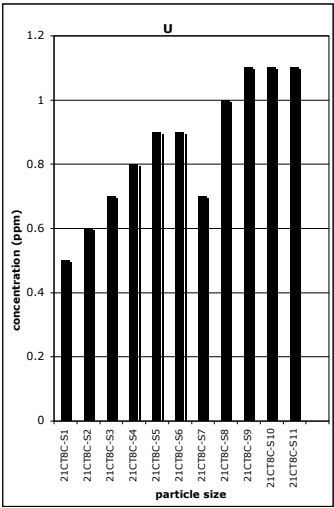
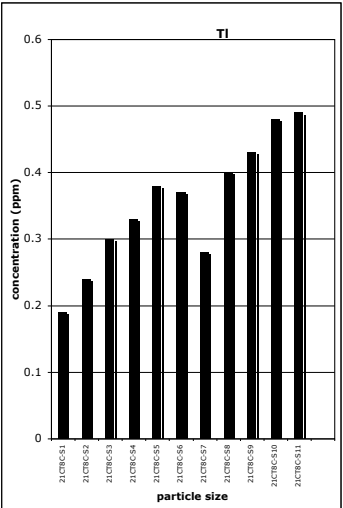
ME-MS61 Sn ppm	ME-MS61 Sr ppm	ME-MS61 Ta ppm	ME-MS61 Te ppm	ME-MS61 Th ppm	ME-MS61 Ti %
1.3	27.3	0.17	<0.05	1.9	0.123
0.6	33.4	0.2	<0.05	2.3	0.142
0.8	34.3	0.23	<0.05	2.8	0.169
0.7	37.4	0.27	<0.05	3.1	0.186
0.9	41	0.29	<0.05	3.3	0.198
1.1	46	0.3	0.06	3.4	0.225
0.8	34.9	0.21	<0.05	2.4	0.218
1	47	0.31	0.05	3.4	0.225
1.6	50.7	0.36	0.05	4.2	0.278
2.3	51.3	0.38	0.09	4.3	0.3
4.8	51.4	0.42	0.08	4.6	0.308



S1< 2830 um	1000 um>S4<500 um	125 um>S7<75 um	32 um>S10>20 um
2830 um>S2<1700 um	500 um>S5<250 um	75 um>S8<45 um	20 um>S11
1700 um>S3<1000 um	250 um>S6<125 um	45 um>S9<32 um	

Elemental Distribution (by Concentration) vs. Particle Size

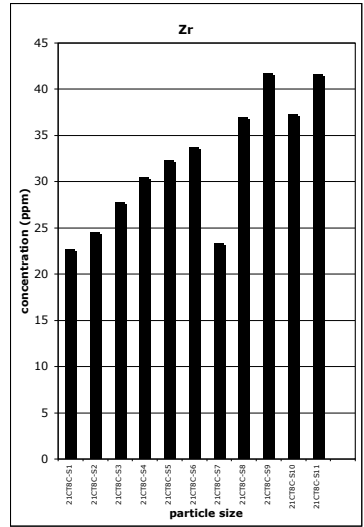
ME-MS61 Tl ppm	ME-MS61 U ppm	ME-MS61 V ppm	ME-MS61 W ppm	ME-MS61 Y ppm	ME-MS61 Zn ppm
0.19	0.5	58	0.7	5.4	56
0.24	0.6	72	1.2	7.2	84
0.3	0.7	79	0.8	7.9	108
0.33	0.8	91	1.1	9	106
0.38	0.9	101	0.9	10.4	122
0.37	0.9	105	1.2	10.8	129
0.28	0.7	98	0.7	7.8	127
0.4	1	98	1	11.7	114
0.43	1.1	110	1.1	14.3	142
0.48	1.1	114	1.2	14.6	131
0.49	1.1	108	1.4	15	118



S1> 2830 um	1000 um>S4>500 um	125 um>S7>75 um	32 um>S10>20 um
2830 um>S2>1700 um	500 um>S5>250 um	75 um>S8>45 um	20 um>S11
1700 um>S3>1000 um	250 um>S6>125 um	45 um>S9>32 um	

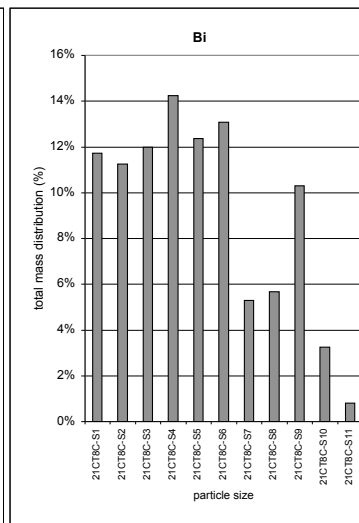
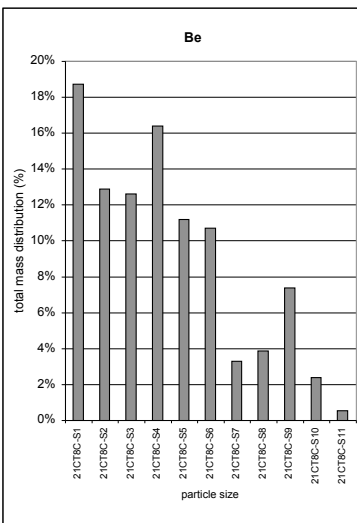
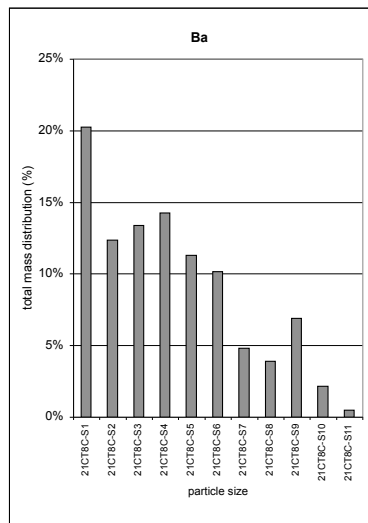
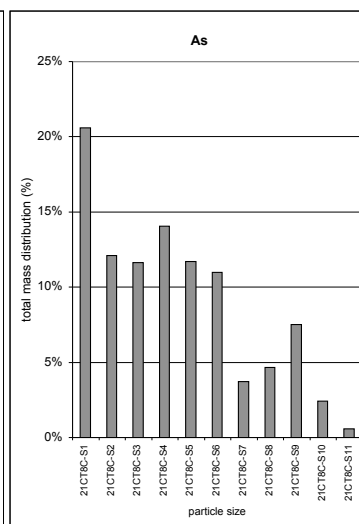
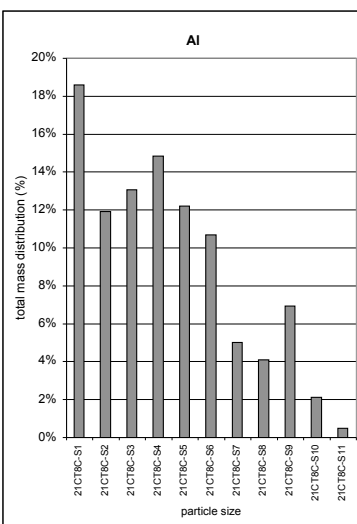
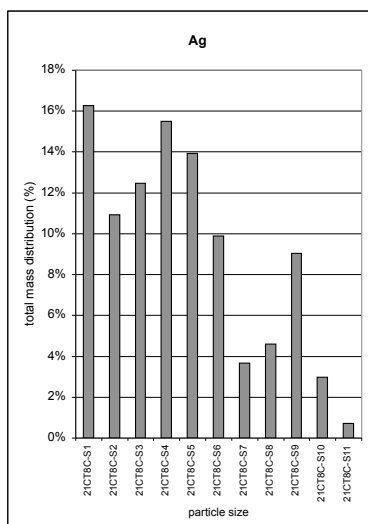
Elemental Distribution (by Concentration) vs. Particle Size

ME-MS61
Zr
ppm
22.7
24.5
27.8
30.4
32.3
33.7
23.3
37
41.7
37.3
41.6



Elemental Distribution (by Mass %) vs. Particle Size

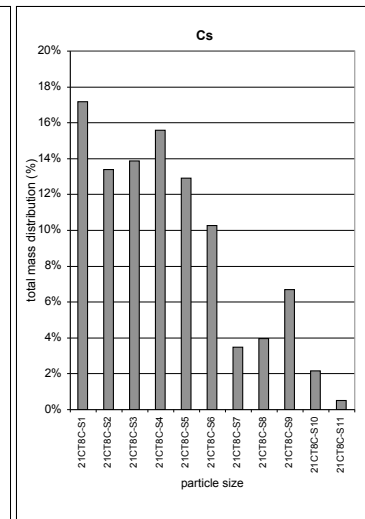
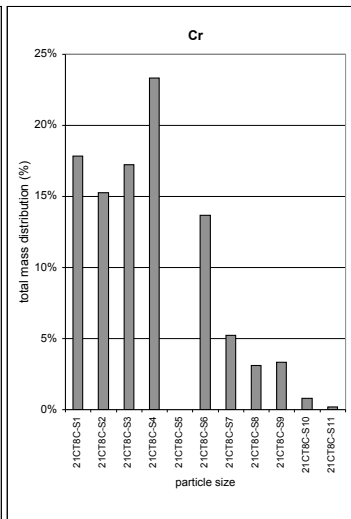
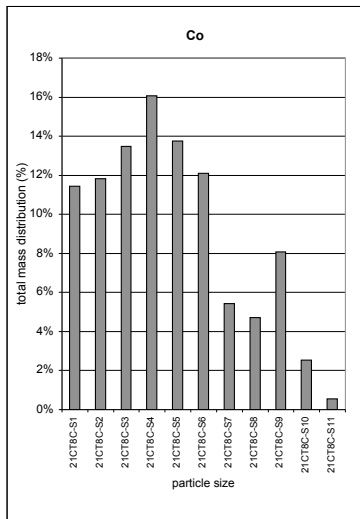
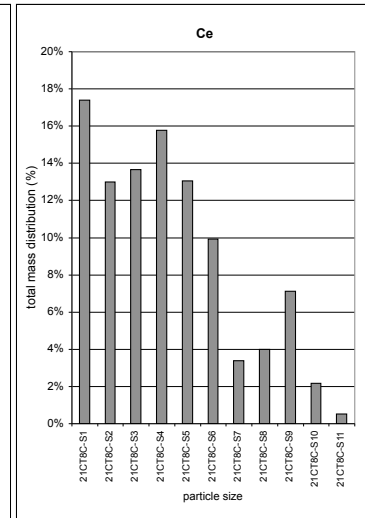
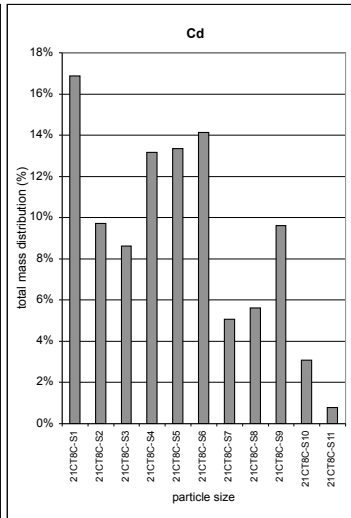
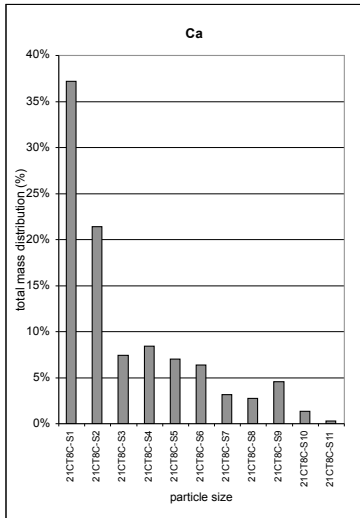
TOTAL MASS (mg)		0.08	28298.38	4.97	178.95	0.47	0.05
BULK CONC (ppm)		0.10	34480.78	6.05	218.05	0.57	0.07
SAMPLE	Recvd Wt.	Ag	Al	As	Ba	Be	Bi
DESCRIPTION		%	%	%	%	%	%
21CT8C-S1	-	16%	19%	21%	20%	19%	12%
21CT8C-S2	-	11%	12%	12%	12%	13%	11%
21CT8C-S3	-	12%	13%	12%	13%	13%	12%
21CT8C-S4	-	16%	15%	14%	14%	16%	14%
21CT8C-S5	-	14%	12%	12%	11%	11%	12%
21CT8C-S6	-	10%	11%	11%	10%	11%	13%
21CT8C-S7	-	4%	5%	4%	5%	3%	5%
21CT8C-S8	-	5%	4%	5%	4%	4%	6%
21CT8C-S9	-	9%	7%	8%	7%	7%	10%
21CT8C-S10	-	3%	2%	2%	2%	2%	3%
21CT8C-S11	-	1%	0%	1%	0%	1%	1%



S1> 2830 um
 2830 um>**S2**>1700 um
 1700 um>**S3**>1000 um
 1000 um>**S4**>500 um
 500 um>**S5**>250 um
 250 um>**S6**>125 um
 125 um>**S7**>75 um
 75 um>**S8**>45 um
 45 um>**S9**>32 um
 32 um>**S10**>20 um
 20 um>**S11**

Elemental Distribution (by Mass %) vs. Particle Size

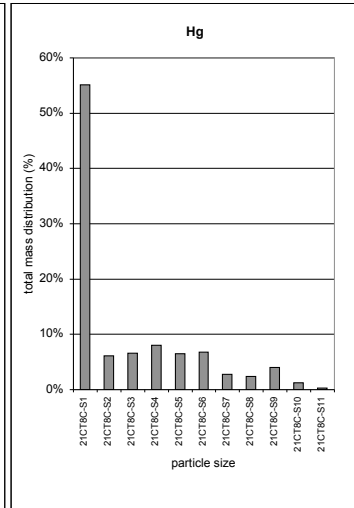
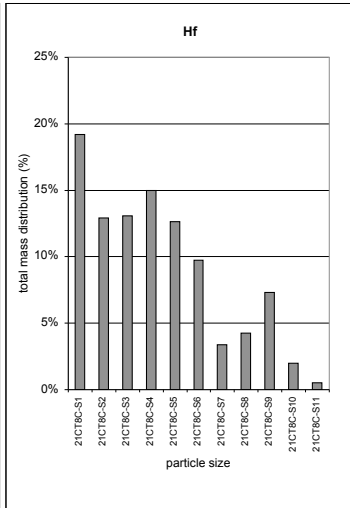
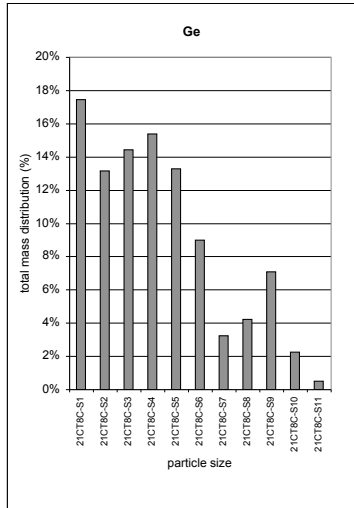
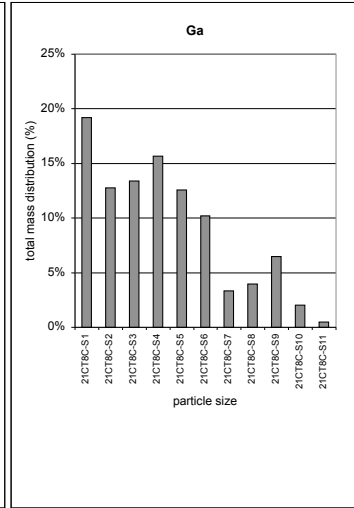
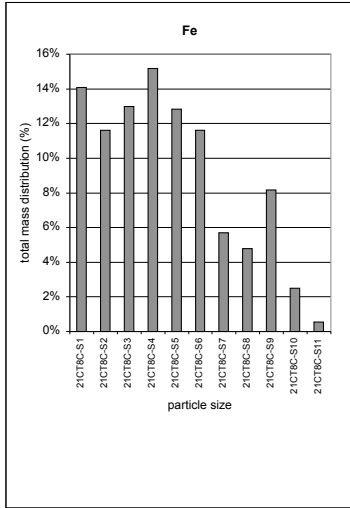
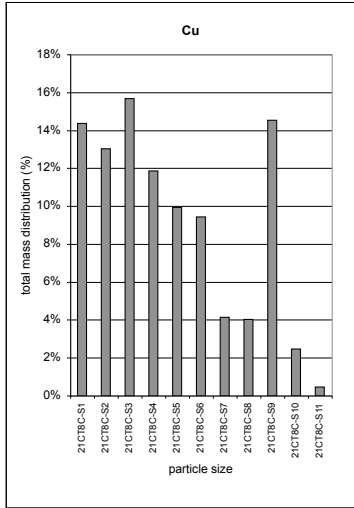
1318.24	0.05	15.69	112.10	3597.30	1.37
1606.24	0.06	19.12	136.59	4383.21	1.66
Ca	Cd	Ce	Co	Cr	Cs
%	%	%	%	%	%
37%	17%	17%	11%	18%	17%
21%	10%	13%	12%	15%	13%
7%	9%	14%	13%	17%	14%
8%	13%	16%	16%	23%	16%
7%	13%	13%	14%	0%	13%
6%	14%	10%	12%	14%	10%
3%	5%	3%	5%	5%	3%
3%	6%	4%	5%	3%	4%
5%	10%	7%	8%	3%	7%
1%	3%	2%	3%	1%	2%
0%	1%	1%	1%	0%	1%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

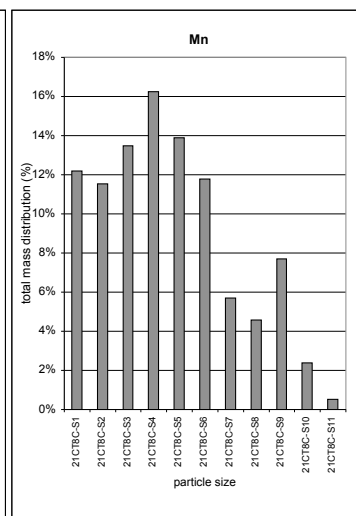
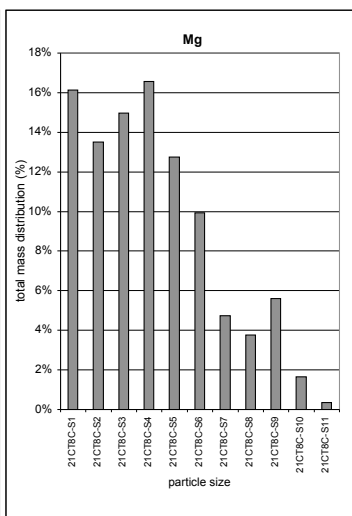
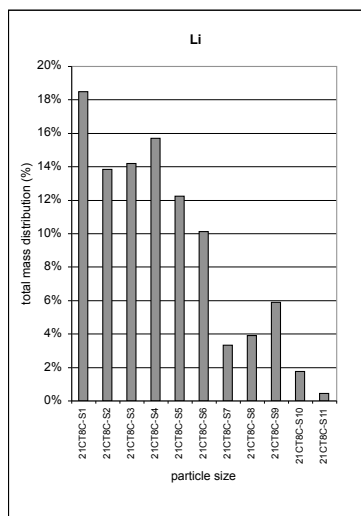
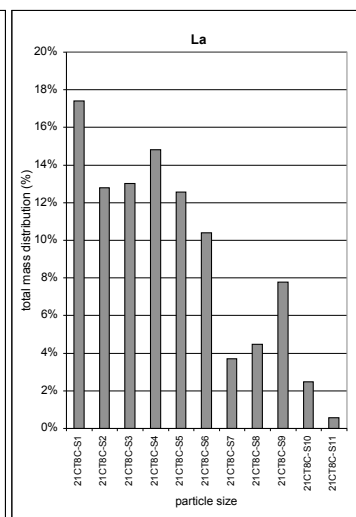
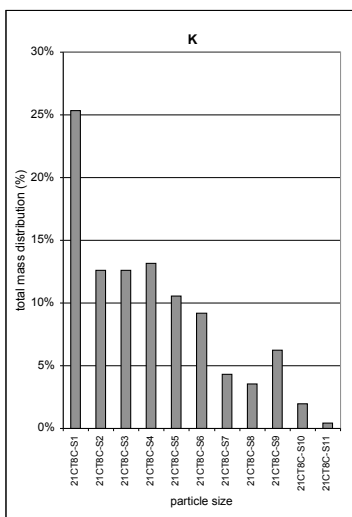
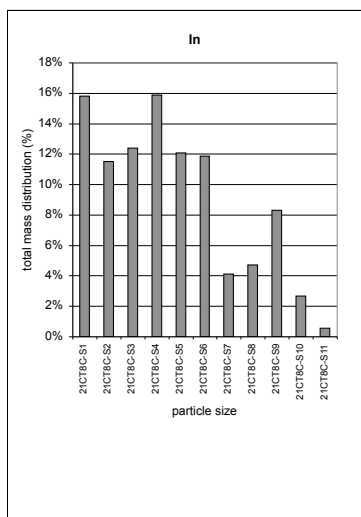
50.97	64051.13	6.74	0.16	0.67	25.66
62.11	78044.51	8.21	0.19	0.81	31.27
Cu	Fe	Ga	Ge	Hf	Hg
%	%	%	%	%	%
14%	14%	19%	17%	19%	55%
13%	12%	13%	13%	13%	6%
16%	13%	13%	14%	13%	7%
12%	15%	16%	15%	15%	8%
10%	13%	13%	13%	13%	7%
9%	12%	10%	9%	10%	7%
4%	6%	3%	3%	3%	3%
4%	5%	4%	4%	4%	2%
15%	8%	6%	7%	7%	4%
2%	3%	2%	2%	2%	1%
0%	1%	0%	1%	1%	0%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

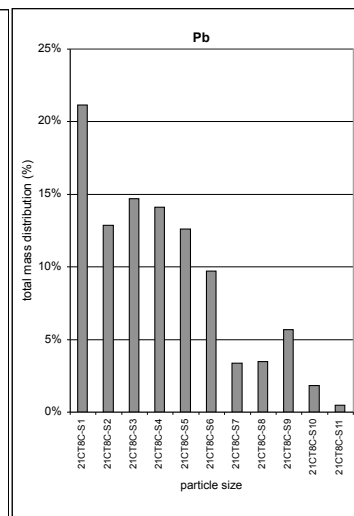
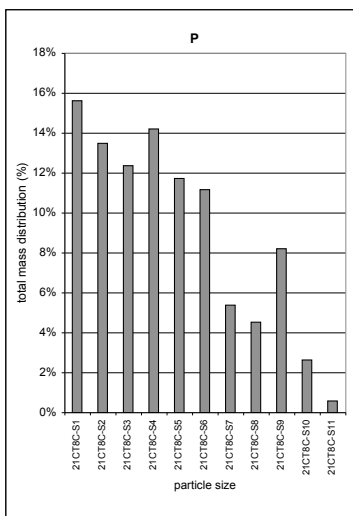
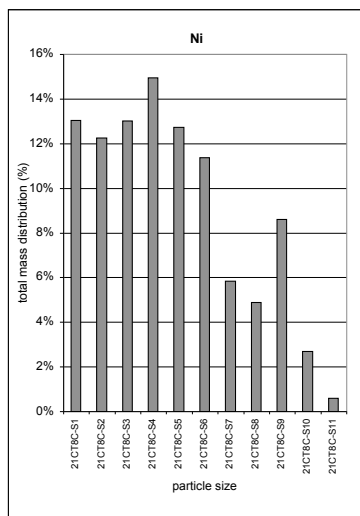
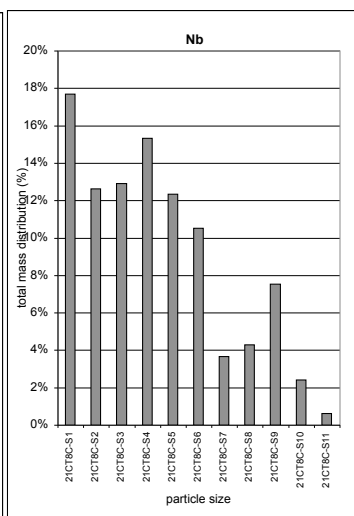
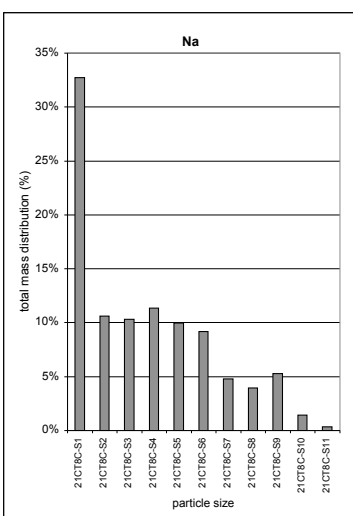
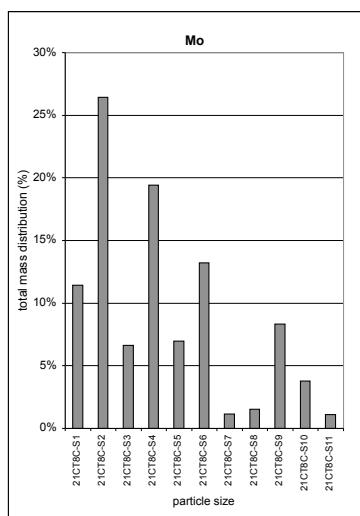
0.02	3113.89	7.11	17.29	15729.94	901.24
0.02	3794.19	8.66	21.07	19166.49	1098.13
In	K	La	Li	Mg	Mn
%	%	%	%	%	%
16%	25%	17%	18%	16%	12%
12%	13%	13%	14%	14%	12%
12%	13%	13%	14%	15%	13%
16%	13%	15%	16%	17%	16%
12%	11%	13%	12%	13%	14%
12%	9%	10%	10%	10%	12%
4%	4%	4%	3%	5%	6%
5%	4%	4%	4%	4%	5%
8%	6%	8%	6%	6%	8%
3%	2%	2%	2%	2%	2%
1%	0%	1%	0%	0%	1%



S1 > 2830 um	1000 um> S4 >500 um	125 um> S7 >75 um	32 um> S10 >20 um
2830 um> S2 >1700 um	500 um> S5 >250 um	75 um> S8 >45 um	20 um> S11
1700 um> S3 >1000 um	250 um> S6 >125 um	45 um> S9 >32 um	

Elemental Distribution (by Mass %) vs. Particle Size

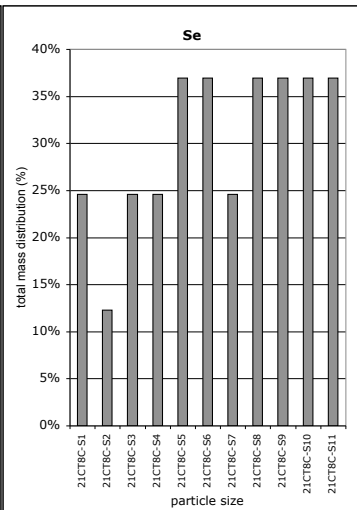
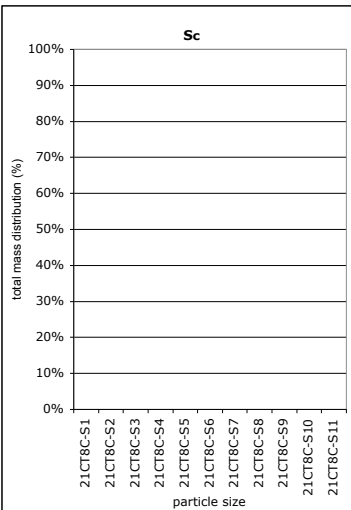
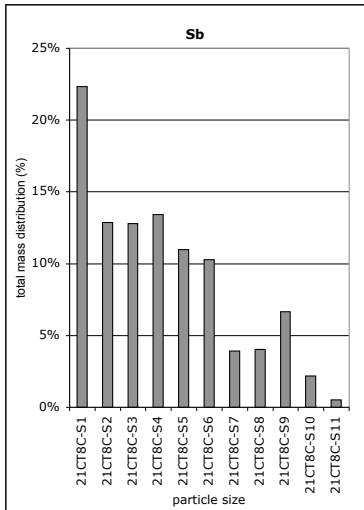
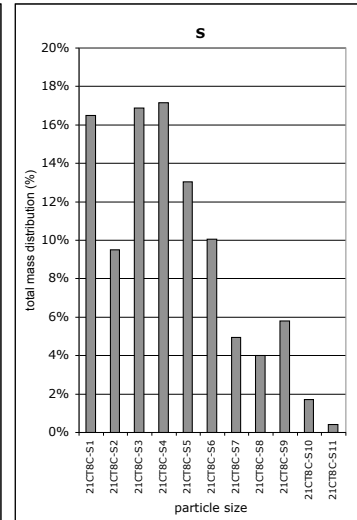
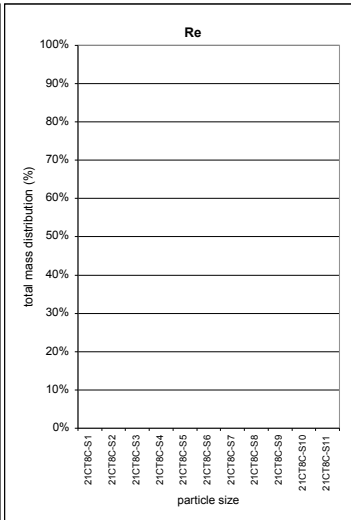
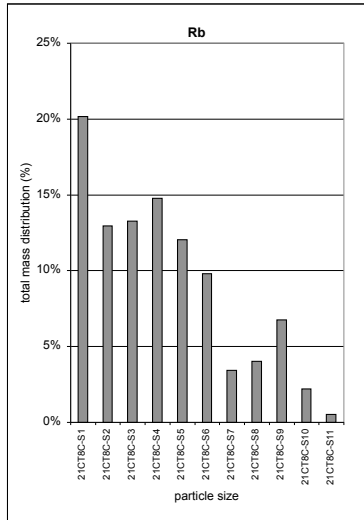
1.40	2540.22	2.53	1927.33	273.01	5.34
1.70	3095.19	3.08	2348.39	332.66	6.51
Mo	Na	Nb	Ni	P	Pb
%	%	%	%	%	%
11%	33%	18%	13%	16%	21%
26%	11%	13%	12%	13%	13%
7%	10%	13%	13%	12%	15%
19%	11%	15%	15%	14%	14%
7%	10%	12%	13%	12%	13%
13%	9%	11%	11%	11%	10%
1%	5%	4%	6%	5%	3%
2%	4%	4%	5%	5%	3%
8%	5%	8%	9%	8%	6%
4%	1%	2%	3%	3%	2%
1%	0%	1%	1%	1%	0%



S1 > 2830 um	1000 um > S4 > 500 um	125 um > S7 > 75 um	32 um > S10 > 20 um
2830 um > S2 > 1700 um	500 um > S5 > 250 um	75 um > S8 > 45 um	20 um > S11
1700 um > S3 > 1000 um	250 um > S6 > 125 um	45 um > S9 > 32 um	

Elemental Distribution (by Mass %) vs. Particle Size

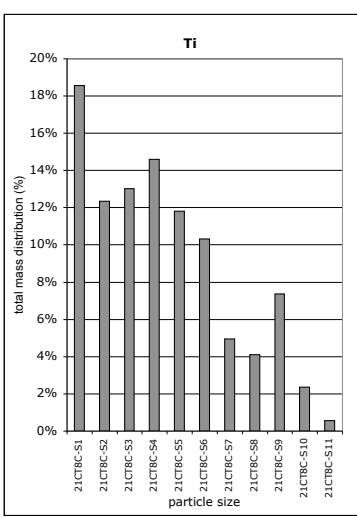
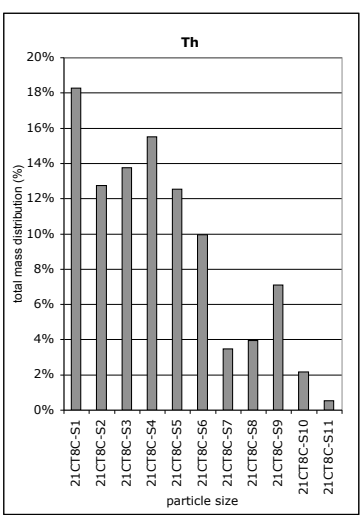
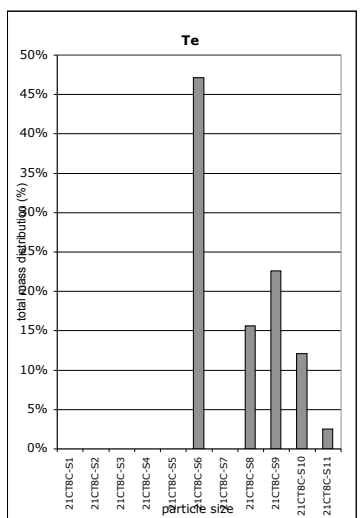
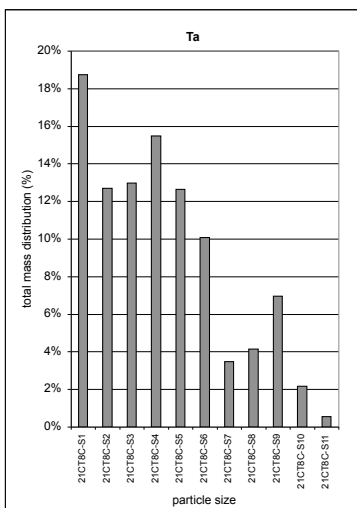
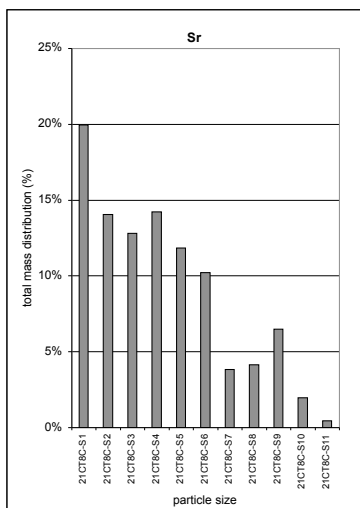
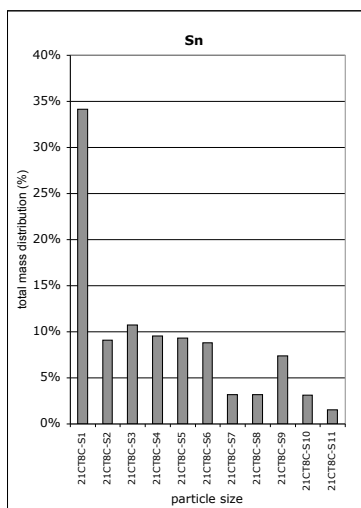
20.29	0.00	129.22	0.86	0.00	1.73
24.72	0.00	157.45	1.05	0.00	2.11
Rb	Re	S	Sb	Sc	Se
%	%	%	%	%	%
20%	#DIV/0!	16%	22%	#DIV/0!	25%
13%	#DIV/0!	10%	13%	#DIV/0!	12%
13%	#DIV/0!	17%	13%	#DIV/0!	25%
15%	#DIV/0!	17%	13%	#DIV/0!	25%
12%	#DIV/0!	13%	11%	#DIV/0!	37%
10%	#DIV/0!	10%	10%	#DIV/0!	37%
3%	#DIV/0!	5%	4%	#DIV/0!	25%
4%	#DIV/0!	4%	4%	#DIV/0!	37%
7%	#DIV/0!	6%	7%	#DIV/0!	37%
2%	#DIV/0!	2%	2%	#DIV/0!	37%
1%	#DIV/0!	0%	1%	#DIV/0!	37%



S1 > 2830 um	1000 um > S4 > 500 um	125 um > S7 > 75 um	32 um > S10 > 20 um
2830 um > S2 > 1700 um	500 um > S5 > 250 um	75 um > S8 > 45 um	20 um > S11
1700 um > S3 > 1000 um	250 um > S6 > 125 um	45 um > S9 > 32 um	

Elemental Distribution (by Mass %) vs. Particle Size

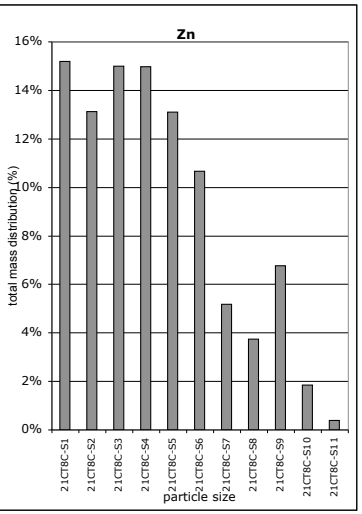
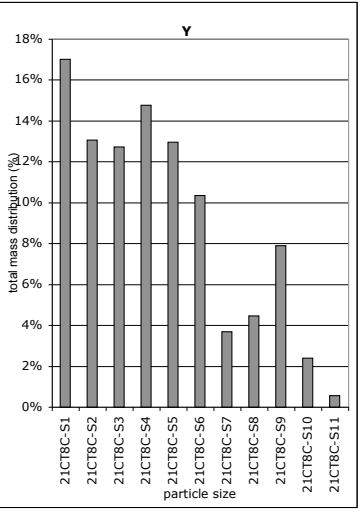
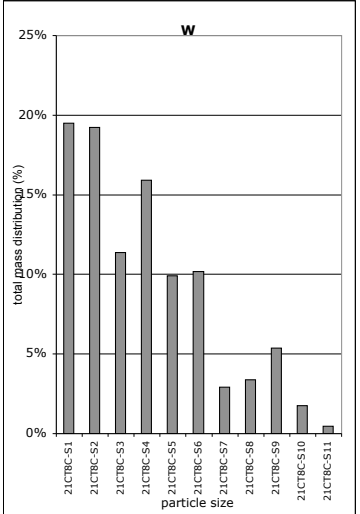
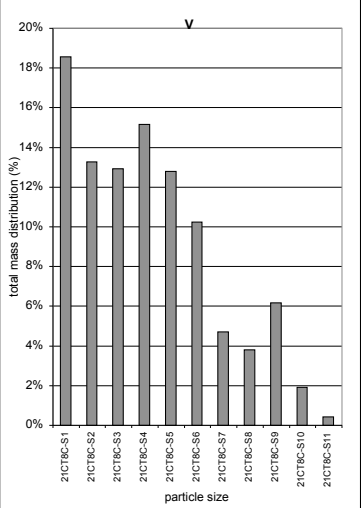
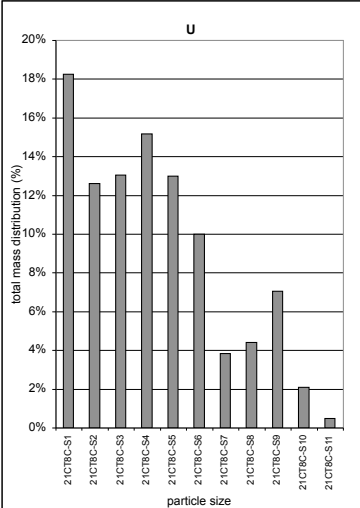
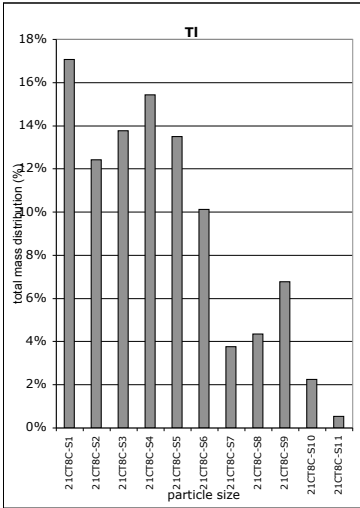
0.81	29.18	0.19	0.01	2.22	1413.33
0.99	35.56	0.24	0.01	2.70	1722.10
Sn % 34% 9% 11% 10% 9% 9% 3% 3% 7% 3% 2%	Sr % 20% 14% 13% 14% 12% 10% 4% 4% 7% 2% 0%	Ta % 19% 13% 13% 15% 13% 10% 3% 4% 7% 2% 1%	Te % 0% 0% 0% 0% 0% 47% 0% 16% 23% 12% 3%	Th % 18% 13% 14% 16% 13% 10% 3% 4% 7% 2% 1%	Ti % 19% 12% 13% 15% 12% 10% 5% 4% 7% 2% 1%



	S1 > 2830 um 2830 um > S2 > 1700 um 1700 um > S3 > 1000 um	1000 um > S4 > 500 um 500 um > S5 > 250 um 250 um > S6 > 125 um	125 um > S7 > 75 um 75 um > S8 > 45 um 45 um > S9 > 32 um	32 um > S10 > 20 um > S11
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Elemental Distribution (by Mass %) vs. Particle Size

0.24		0.58		66.57		0.77		6.76		78.53	
0.29		0.71		81.12		0.93		8.24		95.68	
Ti		U		V		W		Y		Zn	
%		%		%		%		%		%	
17%		18%		19%		19%		17%		15%	
12%		13%		13%		19%		13%		13%	
14%		13%		13%		11%		13%		15%	
15%		15%		15%		16%		15%		15%	
13%		13%		13%		10%		13%		13%	
10%		10%		10%		10%		10%		11%	
4%		4%		5%		3%		4%		5%	
4%		4%		4%		3%		4%		4%	
7%		7%		6%		5%		8%		7%	
2%		2%		2%		2%		2%		2%	
1%		0%		0%		0%		1%		0%	



10>20 um
11

S1> 2830 um
2830 um>S2>1700 um
1700 um>S3>1000 um

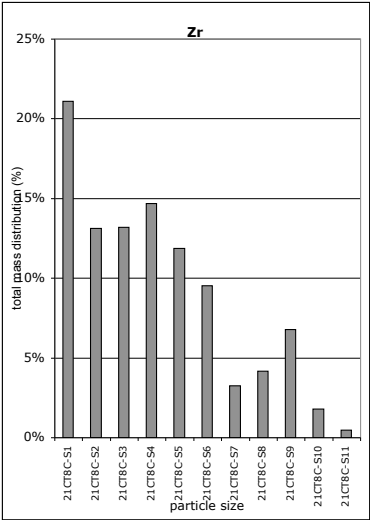
1000 um>S4>500 um
500 um>S5>250 um
250 um>S6>125 um

125 um>S7>75 um
75 um>S8>45 um
45 um>S9>32 um

32 um>S10>
20 um>S11

Elemental Distribution (by Mass %) vs. Particle Size

	22.94
	27.96
Zr	
%	
21%	
13%	
13%	
15%	
12%	
10%	
3%	
4%	
7%	
2%	
0%	



10>20 um
11

Elemental Concentration Trend Categorization

Sample

21CT8C

Direct	Inverse	Unimodal (max)	Bimodal (2 max)	Reverse Unimodal (min)	Constant	Poor	Below Detection
	Al	Cu (S9)	Ag (S5,S11)		Mg	Mo	Re
	Ba	Na (S8)	As (S6,S11)		S		Te
	Bi		Cd (S6,S11)				
	Ca		Ce (S5,S11)				
	Fe		Co (S6,S10)				
	Hg		Cr (S4,S6)				
	K		Cs (S6,S11)				
	Mn		Ga (S6,S10)				
	Ni		Ge (S5,S10)				
	P		In (S6,S10)				
	Sn		La (S6,S10)				
	Ti		Li (S6,S11)				
			Nb (S6,S11)				
			Pb (S6,S11)				
			Rb (S6,S11)				
			Sb (S6,S11)				
			Se (S6,S8)				
			Sr (S6,S11)				
			Ta (S6,S11)				
			Tl (S5,S11)				
			U (S6,S9)				
			V (S6,S10)				
			Y (S6,S11)				
			Zn (S6,S9)				
			Be (S4,6)				
			Hf (S6,9)				
			W (S2,6)				
			Zr (S6,9)				