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Lead Isotope Database of Unpublished Results from Sulfide Mineral Occurrences—California, Idaho, Oregon, and Washington

By S. E. Church

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Contents

Tables

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Introduction

The Pb isotope database for sulfide deposits and occurrences in the Western United States was funded by the Mineral Resources Program, U.S. Geological Survey (USGS). Reports on Pb isotope data from Alaska were published in Church and others (1987a) and Gaccetta and Church (1989). The primary objectives of the project were three-fold:

- To utilize Pb isotope signatures, in conjunction with the regional mapping, to assess the relative ages and to categorize the types of deposits studied,
- To relate the Pb isotope and trace-element geochemical signatures of specific deposits and occurrences to ore-forming processes, and
- To use the Pb isotope data to correlate lithotectonic terranes within the northern Cordillera.

The report by Church and others (1987b) shows how this fingerprinting methodology can be applied to trace the offset of lithostratigraphic terranes.

Presentation of the Data

The Pb isotopic data presented in tables 1–4 represent the work completed on sulfide mineral deposits located in California, Oregon, Idaho, and Washington from 1986 through 1995 when the project was terminated due to reductions in funding. The data are reported here for use by investigators who may find them to be of value in mineral exploration. No attempt will be made in this report to summarize the voluminous literature on these ore deposits.

Deposit Information

Geologic and site information on each specific deposit or occurrence has been provided largely by the sample contributor on the form used for sample submission. All sites have been evaluated by comparing the data provided against the data in the USGS Mineral Resource Data System (MRDS; accessed June 29, 2010; *http://tin.er.usgs.gov/mrds/*). Specific geologic information on the deposit or occurrence also has been obtained from published literature referenced therein. Contributors were given the opportunity to modify the descriptive data in the tables. This process should have minimized errors. The deposit classification used in this report is based on the compilation by Cox and Singer (1986) and is included here only for the purpose of dialogue. There is not widespread agreement among geologists on the classification of deposits into model types.

Since some of the samples have been obtained from museums (see table 5 for identification criteria), the localities of the samples may have a higher level of uncertainty associated with them. Some additional caution should be applied when using data from museum samples.

Chemistry and Mass Spectrometry

All of the Pb isotope data presented in tables 1–4 have been analyzed using the silica-gel emitter method (Cameron and others, 1969). Terms used in the data tables are defined in table 5. The Pb isotope data have all been corrected for thermal fractionation using the NBS SRM-981 common-Pb standard (Catanzaro and others, 1968) and are accurate, at the 2 sigma level, to within ± 0.1 percent or better.

We report analyses from two types of samples: analyses made on those that contain galena (PbS, indicated by Gn in the sample mineralogy column) or tetrahedrite (TT) that could be hand separated, and analyses on either mixed sulfides. Lead isotopic determinations have been made largely on mixed sulfides. Where mixed sulfides have been analyzed, we have given the Pb concentration in the sample determined either by direct-current-arc emission spectrography or by atomic absorption spectrophotometry in the solution used for Pb isotopic analysis. Previous studies of mixed sulfides, or of separate sulfide minerals that have 100 ppm or more of Pb, indicate that the Pb isotopic data obtained from this type of sample were comparable to those obtained from galena (for example, Church and others, 1986; Gulson, 1986).

Several different chemical procedures have been used on special samples analyzed in this study. In general, galena has been hand-picked for analysis where possible. Galena samples were prepared for analysis by digestion with ultrapure warm 16M HNO_3 (2–5 mg in 1 mL). The samples were then diluted to 10 mL with deionized water and sufficient solution pipetted out that 1 µg of Pb was available for analysis (usually about 10 µL). Mixed sulfides were digested in hot ultrapure 12M HCl, 16M HNO_3, or aqua regia. The solution was decanted, evaporated to dryness, and converted first to the chloride medium and then to the bromide medium. Lead was isolated from other cations using anion exchange resin in the bromide medium. Ultrapure reagents were used throughout the procedure. Analytical blanks were less than 2.5 ng and have a negligible impact on the reported Pb isotope ratios. The sample was loaded on the anion exchange resin in 0.75M–1.0M HBr, washed with l.0M HBr and then with 1.5M HC1. The Pb was then eluted with 6M HC1. Molybdenite samples were prepared by digestion in hot ultrapure 6M HC1. A white precipitate, probably $Mo_3Cl_4(OH)_2 \cdot 2H_2O$, formed and the Pb remained in solution. The solution was decanted, evaporated to dryness, and converted to the HBr medium. Lead was purified by anion exchange in the bromide medium. Sulfide samples containing high concentrations of Sb-bearing sulfides required special preparation because Sb is also adsorbed on the anion exchange resin (AG-1) in the bromide medium. These samples (tetrahedrite-bearing samples) were digested in ultrapure 12M HC1 in quartz beakers. The sample was then heated to dryness driving off much of the volatile $SbCl_3$ and leaving Pb in the residue. The sample residue was dissolved in HBr and final separation of the Pb was done by anion exchange in the bromide medium. Rarely was it necessary to electroplate the Pb samples obtained from the column-separation procedure prior to mass spectrometric analysis, however, when necessary, electro-deposition on a platinum anode was used.

Mass Spectrometer

The isotopic composition of Pb determined at the U.S. Geological Survey, Denver, Colo. was determined using a 30.5 cm, 68° sector, solid-source mass spectrometer of NBS (National Bureau of Standards) design. This instrument was completely rebuilt by W.A. Bowman at the National Bureau of

Standards. Samples were analyzed by Jerry Gaccetta (JG, 1987–1989) and Robert Vaughn (RV, 1991–1995) using the single Re-filament, silica-gel emitter technique at 1250 ± 20°C (Cameron and others, 1969). A minimum of two sets of eight ratio pairs for $^{206}Pb/^{204}Pb$ and one set each of eight ratio pairs for $^{207}Pb/^{206}Pb$ and for $^{208}Pb/^{206}Pb$ were taken over a period of 30 to 40 minutes in a typical analysis using peak-hopping by controlling the magnetic field (Bigelow and others, 1999). A second set of Pb isotope data also was taken if the ion beam remained stable to improve analytical statistics.

Results

The analytical data are summarized in tables 1–4. The data in all four tables are organized in the same manner. Data are first ordered by mineral deposit type; second, alphabetically by deposit name; and finally by sample number. A few samples were analyzed more than once to evaluate long-term reproducibility of the data. Table 1 presents the Pb isotope results from deposits north of the Columbia River Basalt field in Washington to the Canadian border. One sample from the Lynx pit on Vancouver Island was also analyzed and is included in this data table. Table 2 presents the Pb isotope results from the Blue Mountains in central and eastern Oregon and western Idaho. Table 3 presents the Pb isotope results from the Klamath Mountains in western Oregon and northern California. Table 4 presents the Pb isotope results from the Shasta mining district and from the California foothills belt in northern and central California. Table 5 summarizes the abbreviations used in the data tables to convey the maximum amount of information using the least amount of space.

Table 1. Compilation of geologic, mineral deposit type, sample mineralogy, U, Th, and Pb concentrations, and Pb isotope data for samples from northern Washington.

Deposit Name	Sample No.	Host Age	Dep. Type	Latitude DMS	Longitude DMS	Pb isotope ratios $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Pb Conc ppm	U Conc ppm	Th Conc ppm	Mineralogy	Mass Spectrometry Analyst
Belcher	OD18859	K-T	Au-SKN	48 43 26	118 32 46	19.478	15.650	38.474	12	3.3	0.007	py	JG
Cooke Mountain	OD18878	K-T	Au-SKN	48 42 27	118 33 00	21.900	15.788	38.581	2.5	3.1	0.13	py	JG
Big Iron Mountain	OD18865	K-T	Au-SKN	48 33 34	118 35 52	18.921	15.635	38.797	5.2	0.20	0.021	py	JG
Republic, Knob Hill ore	GP9-N112	K-T	Au-SKN	48 40 05	118 44 55	18.526	15.616	38.784	3,000	--	--	py	JG
Republic, Knob Hill ore	EB GP-2	K-T	Au-SKN	48 40 05	118 44 55	18.652	15.600	38.744	100	--	--	py	JG
Aslhend Hill	89WASAH	--	MVT	48 42 30	117 53 30	18.493	15.693	38.257	na	--	--	Gn	JG
Cedar Creek	BCC-1-165	D	MVT	48 47 51	117 26 53	19.396	15.763	39.733	na	--	--	Gn	JG
Cedar Creek	BCC-1-119	D	MVT	48 47 51	117 26 53	19.364	15.748	39.682	na	--	--	Gn	JG
Cedar Creek	BCC-5-80	D	MVT	48 47 51	117 26 53	19.368	15.747	39.736	na	--	--	Gn, sl	JG
Hubbard (stratiform ore)	89WAHB-1	D	MVT	48 55 16	117 52 02	19.830	15.740	39.592	na	--	--	Gn	JG
Hubbard (vein ore)	89WAHV-1	D	MVT	48 55 16	117 52 02	19.856	15.749	39.625	na	--	--	Gn	JG
Pend Oreille Mine													
Yellowhead ore zone	92ABYH-1	lC	MVT	48 53	117 22	19.694	15.814	40.348	1,000	--	--	sl, gn	RV
Yellowhead ore zone	92ABYH-2	C-O	MVT	48 53	117 22	19.769	15.849	40.523	1,450	--	--	sl, gn	RV
Yellowhead ore zone	92ABYH-3	C-O	MVT	48 53	117 22	19.762	15.820	40.424	1,220	--	--	sl, gn	RV
Josephine ore zone	92ABJS-1	mO	MVT	48 53	117 22	19.520	15.793	39.987	2,500	--	--	sl, gn	RV
Josephine ore zone	92ABJS-2	mO	MVT	48 53	117 22	19.552	15.992	40.064	2,500	--	--	sl, gn	RV
Josephine ore zone	92ABJS-3	mO	MVT	48 53	117 22	19.507	15.793	39.948	930	--	--	sl, gn	RV
Josephine ore zone	92ABJS-4	mO	MVT	48 53	117 22	19.462	15.855	40.063	1,830	--	--	sl, gn	RV
Josephine ore zone	92ABJS-5	mO	MVT	48 53	117 22	19.393	15.784	39.810	2,000	--	--	sl, gn	RV
Alder Mine	86WAAL-4	J	VMS	48 19 10	120 09 50	18.819	15.602	38.460	2,200	--	--	py, cp	JG
Blue Mountain prospect	GP3418	J	VMS	47 48 42	121 28 12	18.888	15.605	38.648	30	--	--	cp	MD
Bonanza	89WABZ-1	D/C	VMS	48 43 31	117 47 10	18.326	15.682	38.311	na	--	--	Gn	JG
Bonanza	89WABZ-1 dup	D/C	VMS	48 43 31	117 47 10	18.339	15.700	38.359	na	--	--	Gn	JG
California Mine	86WACL-4	J	VMS	48 36 10	118 34 50	18.974	15.696	38.646	na	--	--	py, cp, Gn	JG
Copper World extension	86WACWE-3	P-Tr	VMS	48 51 10	119 35 30	18.160	15.540	37.793	90	0.065	0.34	py, cp, po	JG
Empire Creek	DDH3-293	P-Tr	VMS/HV?	48 49 15	118 41 30	18.855	15.623	38.409	1,200	--	--	sl, gn, py	JG
Glacier (Midas)	1492	lJ-eK	VMS	48 53 30	121 55 00	18.301	15.531	37.925	na	--	--	py, cp, Gn	JG
Great Excelsior	86WAEX-3	J	VMS	48 53 50	121 48 50	18.767	15.600	38.318	3.1	0.024	0.001	py	JG
Great Excelsior	86WAEX-4	J	VMS	48 53 50	121 48 50	19.325	15.647	38.624	400	14	1.0	po	JG
Great Excelsior	89WAEX-1	J	VMS	48 53 50	121 48 50	18.673	15.578	38.206	2,300	--	--	tt, py	JG
Holden	GP3390	lTr	VMS	48 11 45	120 46 50	18.366	15.566	38.056	300	--	--	py	MD
Holden	Holden-GN	lTr	VMS	48 11 45	120 46 50	18.312	15.542	37.974	na	--	--	Gn	MD
Holden	OD6609	lTr	VMS	48 11 45	120 46 50	18.380	15.557	38.025	10	0.010	0.070	sl	JG
Lockwood pyrite	85WALW-4	J	VMS	47 57 45	121 43 00	18.315	15.548	38.044	35	--	--	py	MD
Lone Star (Attwood)	86WALS-1	J	VMS	48 59 40	118 36 15	19.346	15.660	38.670	36	12	0.92	py, cp, sl	JG
Lone Star (Attwood)	DDH7-298	J	VMS	48 59 40	118 36 15	19.110	15.635	38.546	60	0.49	0.020	cp	JG
Longstreet Mine	86WALST-1	O?	VMS	48 14 10	118 11 45	19.383	15.697	39.236	11	0.49	0.020	tt	JG
Mary Green	GP3388	P	VMS	48 14 25	120 49 10	18.608	15.608	38.274	20	--	--	py	MD
Merchant Mine	GP3378RB	J	VMS	47 49 29	121 26 16	18.958	15.604	38.688	na	--	--	asp, Gn	MD
Western Mines (Lynx Pit)	WM-1	P	VMS	49 34 50	125 36 35	18.543	15.581	38.213	na	--	--	Gn, cp, py	MD
Western Mines (Lynx Pit)	WM-1 dup	P	VMS	49 34 50	125 36 35	18.549	15.565	38.147	na	--	--	Gn	MD

Table 2. Compilation of geologic, mineral deposit type, sample mineralogy, U, Th, and Pb concentrations, and Pb isotope data for samples from Blue Mountains, Oregon and Idaho.

Deposit Name	Sample No.	Host Age	Dep. Type	Latitude DMS	Longitude DMS	Pb isotope ratios $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Pb Conc ppm	U Conc ppm	Th Conc ppm	Mineralogy	Mass Spectrometry Analyst
Bay Horse Mine	89ORBH-2	mTr	HV	44 26 57	117 13 11	18.694	15.588	38.325	na	--	--	TT	JG
Bay Horse Mine	89ORBH-2 dup	mTr	HV	44 26 57	117 13 11	18.705	15.592	38.355	na	--	--	TT	JG
Bay Horse Mine	BH-3	mTr	HV	44 26 57	117 13 11	18.679	15.590	38.354	na	--	--	TT	JG
Blue Jacket	BJ-5-81	mTr	VMS	45 33 25	116 26 10	18.350	15.528	37.917	na	--	--	sl, cp, py, Gn	JG
Blue Jacket	SR-346	mTr	VMS	45 33 25	116 26 10	18.402	15.565	37.995	25	--	--	cp, sl, gn	JG
Buckeye Mine	86ORBY-8	--	HV	44 59 21	117 51 45	18.258	15.518	37.698	140	0.77	0.63	py	JG
Clover Creek Copper	CCR-8	mTr	VMS	44 54 35	117 32 05	18.310	15.576	37.942	210	--	--	ba	JG
Clover Creek Copper	OD11140	lTr	VMS	44 54 35	117 32 05	18.776	15.657	38.546	25	--	--	py	JG
Copper Dyke, 100 ft level	OD17098	--	VMS	44 39 57	118 29 23	18.915	15.694	34.400	450	4.6	0.030	py	JG
Dewey (Patrick Tunnel)	3-2121R	eP	VMS	45 54 35	116 01 45	18.177	15.538	37.703	na	--	--	Gn, sl, cp	JG
Dewey (Patrick Tunnel)	89IDD-1	eP	VMS	45 54 35	116 01 45	18.194	15.535	37.629	7.8	0.010	0.070	py	JG
Dolly Varden	DDH1-35	mTr	VMS	44 56 03	117 22 14	18.197	15.501	37.605	28	0.15	0.10	py	JG
Dolly Varden	DDH1-40	mTr	VMS	44 56 03	117 22 14	18.251	15.565	37.752	110	0.39	0.040	py	JG
Dolly Varden	DDH4-65	mTr	VMS	44 56 03	117 22 14	18.206	15.521	37.663	51	0.12	0.030	py	JG
Dolly Varden	DDH4-70	mTr	VMS	44 56 03	117 22 14	18.177	15.500	37.593	58	0.12	0.010	py	JG
Dolly Varden	DDH6-100	mTr	VMS	44 56 03	117 22 14	18.428	15.551	37.878	7.2	0.030	0.010	py	JG
Dolly Varden	DDH6-190	mTr	VMS	44 56 03	117 22 14	18.413	15.527	37.796	4.7	0.030	0.070	py	JG
Dolly Varden	DDH6-200	mTr	VMS	44 56 03	117 22 14	18.306	15.512	37.694	7.7	0.030	0.060	py	JG
Dolly Varden	DDH7-100	mTr	VMS	44 56 03	117 22 14	18.196	15.509	37.628	55	0.060	0.060	py	JG
Dolly Varden	DDH8-50	mTr	VMS	44 56 03	117 22 14	18.180	15.509	37.625	170	0.070	0.040	py	JG
Dolly Varden	DDH8-55	mTr	VMS	44 56 03	117 22 14	18.283	15.538	37.725	7.1	0.060	0.060	py	JG
Hercules (Cuddy Mountain)	86IDHER-1	mTr	HV	44 46 05	116 52 00	18.704	15.589	38.353	200	--	--	gn	JG
Hercules (Cuddy Mountain)	86IDHER-1 dup	mTr	HV	44 46 05	116 52 00	18.705	15.592	38.355	na	--	--	Gn	JG
Idaho prospect	89IDRQP	eP	VMS	45 00 45	116 47 30	18.292	15.507	37.710	5.8	0.13	0.18	ml, py	JG
Imperial Mine, Eagle vein	Imp-Eag	--	HV	44 52 00	118 15 20	18.692	15.607	38.432	na	--	--	Gn, cp, sl, py	JG
Imperial Mine, Eagle vein	OD2023	--	HV	44 52 00	118 15 20	18.697	15.608	38.406	na	--	--	Gn, cp, sl, asp, py	RV
Imperial Mine, Eagle vein	OD2023 dup	--	HV	44 52 00	118 15 20	18.687	15.597	38.383	na	--	--	Gn, cp, sl, asp, py	RV
Iron Dyke Mine	IDC-122	eP	VMS	45 01 37	116 51 27	18.212	15.521	37.710	na	--	--	Gn, sl, cp, py, tt, ba	JG
Mineral	86IDMIN-1	mTr	HV	44 34 10	117 04 10	18.729	15.628	38.446	30	--	--	tt	JG
Mother Lode (Keating dist.)	BC-3	mTr	VMS	44 55 00	117 28 38	18.302	15.528	37.758	630	--	--	py, cp, sl	JG
Mother Lode (Keating dist.)	BC-9	mTr	VMS	44 55 00	117 28 38	18.633	15.674	38.253	3.6	0.018	0.018	py	JG
Oregon King Mine	OKM-1	T	HV	44 45 09	120 44 19	19.002	15.608	38.702	na	--	--	Gn, sl, cp	MD
Overland	OD2032	--	HV	44 51 53	118 16 43	18.724	15.632	38.475	na	--	--	Gn, st	JG
Peck Mountain	PM-1-992	mTr	VMS	44 53 00	116 36 00	18.672	15.603	38.381	100	2.1	0.55	cp	JG
Red Jacket, Union vein, level C	OD6249	--	HV	44 59 30	117 11 45	18.628	15.595	38.221	560	--	--	gn, cp	JG
Red Ledge	TG-12-1438	eP	VMS	45 13 44	116 40 07	18.229	15.518	37.753	na	--	--	Gn, sl, py, tt, ba	ALH
River Queen	OD6231	--	VMS	45 03	116 47	18.610	15.588	38.261	5.0	0.008	0.007	cp, tt	JG
River Queen prospect	89IDRQP	eP	VMS	45 00 50	116 46 40	18.289	15.545	37.710	900	0.130	0.180	cp	JG
River Queen prospect	89IDRQP dup	eP	VMS	45 00 50	116 46 40	18.298	15.545	37.791	900	0.130	0.180	cp	JG
Thorne Flat	TF-1	eP	VMS	45 00 39	116 51 01	18.197	15.544	37.733	24	0.021	0.026	py	JG

Table 3. Compilation of geologic, mineral deposit type, sample mineralogy, U, Th, and Pb concentrations, and Pb isotope data for samples from Klamath Mountains, western Oregon and northern California.

Deposit Name	Sample No.	Host Age	Dep. Type	Latitude DMS	Longitude DMS	Pb isotope ratios $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Pb Conc ppm	U Conc ppm	Th Conc ppm	Mineralogy	Mass Spectrometry Analyst
Almeda	ALM-3	lJ	VMS	42 36 36	123 35 03	18.426	15.553	38.189	na	--	--	py, cp, Gn	MD
Banfield	BU-1-640	Tr	VMS	42 50 05	122 55 55	18.748	15.634	38.386	3.0	0.19	0.008	py, cp	JG
Banfield	BU-1-739	Tr	VMS	42 50 05	122 55 55	19.151	15.615	38.580	2.0	0.22	0.20	py	JG
Blue Ledge	BLU-1	J	VMS	41 57 25	123 06 30	18.326	15.545	37.983	800	--	--	py, cp, sl	MD
Copper Bluff	CB-1	--	VMS	41 6 35	123 41 06	18.200	15.530	37.855	1,500	--	--	py, cp	MD
Copper Queen	CQD-2	J	VMS	42 37 11	123 23 32	18.162	15.536	37.868	20	--	--	po, cp	MD
Cowboy	CBY-1	J	VMS	42 01 10	123 36 50	18.465	15.589	38.205	2.4	0.005	0.005	po	JG
Empire Mine/Red Ledge	C-62402	lJ	VMS	42 29 00	123 31 00	18.181	15.518	37.835	132	0.14	0.17	sl	JG
Goff Mine	WB-4	lJ	VMS	42 40 46	123 33 36	18.384	15.556	38.126	360	--	--	ba, sl	JG
Goff Mine	WB-4 dup	lJ	VMS	42 40 46	123 33 36	18.379	15.551	38.146	360	0.17	0.002	ba, sl	JG
Gold Note	GN-2	J	VMS	42 40 02	123 13 39	18.522	15.598	38.326	12	--	--	po, cp	MD
Gray Eagle	GEU-1	lJ	VMS	41 51 36	123 22 20	19.380	15.647	38.184	20	1.7	0.041	po	MD
H&R	DDH5-28	lJ	VMS	42 35 40	123 36 15	18.435	15.546	38.164	65	--	--	cp	JG
H&R	DDH5-55	lJ	VMS	42 35 40	123 36 15	18.449	15.547	38.180	30	--	--	cp	JG
H&R	DDH6-135	lJ	VMS	42 35 40	123 36 15	18.457	15.561	38.192	210	--	--	cp	JG
Island Mountain	IM-2	--	VMS	40 01 54	123 29 48	19.084	15.663	38.897	350	--	--	py	MD
Island Mountain	IM-3	--	VMS	40 01 54	123 29 48	19.067	15.657	38.868	1,500	--	--	py	MD
Lyttle	LM-1	J	VMS	42 02 00	123 36 15	18.383	15.571	38.122	5.9	0.003	0.007	po	JG
Mammoth Lode	MM-3	Tr	VMS	42 45 40	122 57 40	18.729	15.604	38.423	2.3	0.007	0.008	py	JG
Oak Mine	OM-1	Tr	VMS	42 33 12	123 17 59	18.175	15.502	37.723	500	0.017	0.014	sl, py, cp	JG
Queen of Bronze	QB-LCH-C	J	VMS	42 03 01	123 35 51	18.337	15.532	38.014	8.0	0.004	0.001	py, cp	JG
Rowley	RS-11-130	Tr	VMS	42 48 58	122 56 35	18.232	15.542	37.998	260	--	--	py, sl, cp	MD
Silver Pk, lower Umpqua adit	Lu-4-MS	lJ	VMS	42 51 20	123 23 04	18.378	15.544	38.109	80	--	--	ba, py	MD
Squaw Creek	SQ-4	J	VMS	42 01 56	123 04 54	18.338	15.555	38.021	5.8	0.024	0.013	py	JG
Steamboat	C-62418	--	VMS	42 05 03	123 16 15	19.102	15.609	38.814	160	--	--	py, cp	JG
Turner Albright	TAB-33-151	lJ	VMS	42 00 00	123 45 26	18.294	15.560	38.058	120	--	--	cp, py, cal	MD
Waldo	OD6243	J	VMS	42 02 30	123 35 00	18.264	15.550	38.008	1.4	0.001	0.002	cp	JG
Waldo	WD-1	J	VMS	42 02 30	123 35 00	18.516	15.595	38.253	2.2	0.008	0.023	po	JG

Table 4. Compilation of geologic, mineral deposit type, sample mineralogy, U, Th, and Pb concentrations, and Pb isotope data for samples from Shasta mining district and California foothills belt, California.

Deposit Name	Sample No.	Host Age	Dep. Type	Latitude DMS	Longitude DMS	Pb isotope ratios $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	Pb Conc ppm	U Conc ppm	Th Conc ppm	Mineralogy	Mass Spectrometry Analyst
Alabaster Cave	OD5415	--	VMS	38 48 43	121 04 32	18.356	15.587	38.135	6.3	--	--	py, cp	RV
Buchanan Mine	NMNH61396	--	VMS	37 11 13	119 59 27	18.896	15.616	38.559	2.5	--	--	cp	RV
Bully Hill	OD9054	--	VMS	40 47 45	122 11 00	17.980	15.528	37.642	380	--	--	sl, cp, gn, Au, py	JG
Campo Seco (Penn)	DM-5	lJ	VMS	38 13 18	120 52 24	18.284	15.577	38.079	290	--	--	py, sl, cp, bn, tt, gn, ml	RV
Campo Seco (Penn)	OD5566	lJ	VMS	38 13 18	120 52 24	18.302	15.569	38.075	6,000	--	--	py, cp	RV
Campo Seco (Penn)	OD5583	lJ	VMS	38 13 18	120 52 24	18.296	15.565	38.057	na	--	--	cp, sl, Gn, cu	RV
Campo Seco (Penn)	UCB688-20	lJ	VMS	38 13 18	120 52 24	18.278	15.561	38.044	350	--	--	cp, sl, gn	RV
Campo Seco (Penn)	UCB688-41	lJ	VMS	38 13 18	120 52 24	18.265	15.538	37.882	250	--	--	cp	RV
Dairy Farm	OD5729	--	VMS	39 01 51	121 17 17	18.421	15.568	38.174	na	--	--	Gn, sl, cp, py	RV
Dairy Farm	OD5768	--	VMS	39 01 51	121 17 17	18.435	15.598	38.248	1,300	--	--	py, cp	RV
Daulton Mine	UCB160E142	--	VMS	37 06 24	119 58 01	18.359	15.562	38.089	na	--	--	Gn, cp	RV
Daulton Mine	UCB160E36	--	VMS	37 06 24	119 58 01	18.815	15.660	38.657	440	--	--	py, po, cp	RV
Fresno	OD8457	--	VMS	36 53 53	119 40 05	18.715	15.548	37.915	5.4	--	--	py, cp	RV
Green Mountain Mine (Mann)	UCB160E37	--	VMS	40 05 57	120 56 35	18.889	15.690	38.774	1,400	--	--	po	RV
Ione	OD5476	--	VMS	38 23 30	120 57 03	18.269	15.568	38.061	na	--	--	cp, sl, Gn	RV
Jesse Bell	UCB160E212	--	VMS	37 08 26	119 56 52	18.869	15.563	38.314	1.7	--	--	py, cp	RV
Keystone-Union Mine	OD5323	--	VMS	37 58 35	120 38 34	18.291	15.541	37.980	2.4	--	--	cp, sl, gn	RV
Napoleon	OD5692	--	VMS	37 55 39	120 43 44	18.456	15.585	38.281	560	--	--	cp, py, gn	RV
Nassau	OD5626	--	VMS	38 02 40	120 38 53	18.180	15.546	37.909	490	--	--	cp, sl, gn	RV
Newton	DM-2	lJ	VMS	38 20 30	120 53 10	18.131	15.518	37.683	21	--	--	py, cp, cc, sl	RV
Noonday	OD5428	--	VMS	38 38 26	120 47 51	18.351	15.546	37.939	58	--	--	cp, py	RV
Quail Hill	OD8429	--	VMS	37 57 40	120 44 57	18.416	15.561	38.187	na	--	--	cp, sl, Gn	RV
Valley View	DM-3	lJ	VMS	38 58 38	121 15 25	18.335	15.523	37.972	na	--	--	Gn, cp, py, sl, cu	RV
Valley View	OD5853	lJ	VMS	38 58 38	121 15 25	18.790	15.622	38.642	na	--	--	sl, Gn, cp, py	RV

Table 5. Abbreviations used in tables 1––4 defined.

Column Heading	Definition
Deposit Name	Term used by geologist who submitted sample; value if given in parentheses is either the alternative name listed in USGS MRDS database or the mining district name if, without these data, confusion might result from the use of same deposit name in a different mining district.
Sample No.	Samples from museum collections are identified by suffixes on the sample numbers as follows: OD, sample from the Stanford ore deposits collection, collected with permission of M. Einaudi; UCB, University of California, Berkeley geology collection, collected with permission of curator; NMNH, National Museum of Natural History, collected through curator Sorena Sorensen. All other samples were collected by the author or were contributed by geologists working in mineral exploration. DDH, sample collected from diamond drill hole provided by contributor.
Host Age	e, early; m, middle; or l, late geologic time in geologic period. C, Cambrian; O, Ordovician; D, Devonian; D/C, Devonian/Carboniferous; P, Permian; Tr, Triassic; J, Jurassic; K, Cretaceous; and T, Tertiary geologic time periods.
Dep. Type	Mineral deposit type as defined in Cox and Singer (1986); Au-SKN, gold skarn deposit; MVT, Mississippi-Valley type carbonate-hosted deposit; VMS, volcanogenic-hosted massive sulfide deposit; HV, hydrothermal vein, usually polymetallic vein with or without recoverable gold.
Latitude	DMS location expressed in degrees, minutes, seconds (NAD27). Horizontal coordinate information is referenced to North American Datum 1927.
Longitude	DMS location expressed in degrees, minutes, seconds (NAD27)
U, Th, and Pb Conc.	Concentrations expressed in ppm, that is parts per million by weight (μg/g), for the elements U, uranium; Th, thorium; and Pb, lead; na, not analyzed because Pb concentration was high or galena or tetrahedrite was visible in sample; --, concentration not determined. Analytical blank expressed in ng, or parts per billion by weight.
Mineralogy	Au, gold; asp, arsenopyrite; ba, barite; bn, bornite; cal, calcite; cp, chalcopyrite; cu, cubanite?; gn (Gn), galena; ml, malachite; po, pyrohotite; py, pyrite; sl, sphalerite; tt (TT) tetrahedrite. Gn or TT indicates galena or tetrahedrite existed in sample in large enough crystals that they could be readily picked and were analyzed separately using different chemistry.
Mass Spectrometry Analyst	From 1982 through 1986, Maryse Delaveux (MD) performed most of the analyses; one sample was analyzed by Anne LeHuray (ALH). From 1987 through 1989, Jerry Gaccetta (JG) analyzed the samples. From 1992 through 1995 when the MRP mass spectrometry laboratory was closed, Robert Vaughn (RV) analyzed the samples. (The mass spectrometer was subsequently surplused.)

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References Cited

Bigelow, R.C., Vaughn, R.B., Church, S.E., 1999, MASSPEC; A PC program to control and to process data from an automated mass spectrometer: U.S. Geological Survey Open-File Report 99-161, 34 p.

Cameron, A.E., Smith, D.H., and Walker, R.L., 1969, Mass spectrometric analysis of nanogram quantities of lead: Analytical Chemistry, v. 41, p. 525-526.

Catanzaro, E.J., Murphy, T.J., Shields, W.R., and Garner, E.L., 1968, Absolute isotopic abundance ratios of common, equal-atom, and radiogenic lead isotopic standards: Journal of Research, National Bureau of Standards, v. 72A, p. 261-267.

Church, S.E., Delevaux, M.H., and Gray, J.E., 1987a, Pb-isotope data base for sulfides from Alaska, March, 1987: U.S. Geological Survey Open-File Report 87-259, 44 p.

Church, S.E., Gray, J.E., Delevaux, M.H., and LeHuray, A.P., 1987b, Lead-isotope signatures of Devonian-Mississippian massive sulfide deposits in Alaska and their significance to mineral exploration, *in* Elliott, I.L., and Smee, B.W., eds., GEOEXPO/86 Exploration in the North American Cordillera: Assoc. Exploration Geochemists, Ontario, Canada. p. 132-141.

Church, S.E., LeHuray, A.P., Grant, A.R., Delevaux, M.H., and Gray, J.E., 1986, Lead-isotopic data from sulfide minerals from the Cascade Range, Oregon and Washington: Geochimica Cosmochimica Acta, v, 50, p. 317-328.

Cox, D.P., and Singer, D.A., eds., 1986, Mineral deposits models: U.S. Geological Survey Bulletin 1693, 379 p.

Gaccetta, J.D., and Church, S.E., 1989, Lead isotope data base for sulfides from Alaska, December, 1989: U.S. Geological Survey Open-File Report 89-688, 60 p.

Gulson, B.L., 1986, Lead isotopes in mineral exploration—Developments in economic geology: Elsevier, New York, 245 p.