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Lead Isotope Determinations from Sulfide Mineral Occurrences—Russian Far East

Data Series 743

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
Length		
microliter (μL)	0.000034	centimeter (cm)
milliliter (mL)	0.3382	millimeter (mm)
liter (L)	33.82	meter (m)
liter (L)	0.2642	kilometer (km)
Mass		
milligram (mg)	0.000035	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)

1 nanogram (ng) equals 1.0×10^{-9} gram.

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Lead Isotope Determinations from Sulfide Mineral Occurrences—Russian Far East

By Stanley E. Church,[1] Nikolai A. Goryachev,[2] and Vladimir I. Shpikerman[3]

Introduction

The lead isotope database for sulfide deposits and occurrences in the Russian Far East was funded by the Mineral Resources Program, U.S. Geological Survey (USGS) in conjunction with the collaborative studies of mineral resources by the Russian Academy of Sciences and the U. S. Geological Survey (Nokleberg and others, 1996). Comparisons of these data with similar lead isotope data from Alaska published in Church, Delevaux, and others (1987) and Gaccetta and Church (1989) provide a basis for the following three-fold project objectives:

1. To utilize lead isotope signatures, in conjunction with regional mapping, to assess the relative ages and to categorize the types of mineral deposits studied,

2. To relate the lead isotope and trace-element geochemical signatures of specific deposits and occurrences to ore-forming processes, and

3. To use the lead isotope data to correlate lithotectonic terranes within the northern Cordillera (Alaska, Yukon Territories and British Columbia in Canada, and the western Cordillera of the United States).

The report by Church, Gray, and others (1987) shows how this fingerprinting methodology can be applied to trace the offset of lithotectonic (or lithostratigraphic as labeled by some authors) terranes. The lead isotope data presented in table 1 represent the work completed on sulfide mineral deposits located in the Russian Far East from 1993 to 1995, when this study was terminated due to lack of funding. The lead isotope data are reported here for use by investigators who may find them of value in mineral exploration. No attempt is made to summarize the voluminous literature on these mineral deposits.

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Deposit Information

Geologic and site information on each specific deposit or occurrence has been provided largely by the sample contributors on the field 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 at *http://tin.er.usgs. gov/mrds/*). Specific geologic information about the deposit or occurrence was also 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 from the compilation by Cox and Singer (1986) and is included here only for the purpose of dialogue. There is no widespread agreement among geologists on the classification of deposits into model types.

Samples and Analytical Techniques

We report analyses from several types of sulfide samples: first, analyses made on those that contain galena (lead sulfide, indicated by GN in the sample mineralogy column) or tetrahedrite (TT) that could be hand separated, and analyses on either mixed sulfides. In addition, lead isotope determinations have been made largely on samples containing mixed sulfide. Where mixed sulfides were analyzed, we report the lead concentration determined in the sample either by direct-current-arc emission spectrography on the powdered sulfide material or that determined in the solution used for lead isotope analysis by atomic absorption spectrophotometry. Previous studies of mixed sulfides, or of separate sulfide minerals that had 100 part per million (ppm) or more of lead, indicate that the lead isotope 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 were used on samples analyzed in this study. Galena has been handpicked for analysis where possible. Galena samples were prepared for analysis by digestion with ultrapure warm 16 Molar (M) HNO_3 (2–5 milligrams (mg) of galena in 1 mL). The samples

were then diluted to 10 mL with deionized water, analyzed by atomic absorption spectrometry to determined the approximate lead concentration (±10 percent), and sufficient solution pipetted out so that 1 microgram (μg) of lead was available for isotope analysis (usually about 1–10 microliter (μL)).

Mixed sulfides were digested in hot ultrapure 12M HCl, 16M HNO$_3$, or aqua regia, depending upon the sulfide minerals present. 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 (AG-1, Bio-Rad Laboratories, Inc., *https://www.bio-rad.com/*) in the bromide medium. Analytical blanks were less than 2.5 nanogram (ng) and have a negligible impact on the reported lead isotope ratios. The sample was loaded on the anion exchange resin (AG-1) in 0.75M–1.0M HBr, washed with l.0M HBr, and then with 1.5M HC1. The lead was then eluted with 6M HC1.

Molybdenite samples were digested in hot ultrapure 6M HC1. A white precipitate, probably $Mo_3Cl_4(OH)_2 \cdot 2H_2O$, formed and the lead remained in solution. The solution was decanted, evaporated to dryness, and converted to the HBr medium. Lead was purified by anion exchange (AG-1) in the bromide medium.

Samples containing high concentrations of Sb-bearing sulfides required special preparation because antimony is also adsorbed onto 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 evaporated to dryness, driving off much of the volatile SbCl$_3$ and leaving lead in the residue. The sample residue was dissolved in HBr and final separation of the lead was done by anion exchange (AG-1) in the bromide medium.

Following the primary separation of lead from other cations using the HBr column procedure, lead samples were further cleaned in a small HCl anion exchange column prior to analysis. Rarely was it necessary to electroplate the lead samples obtained prior to mass spectrometric analysis, however, when necessary, electro-deposition on a platinum anode was also used; blanks from the electroplating step were <1ng and were neglible.

All of the lead isotope data presented in table 1 have been analyzed using the silica-gel emitter method (Cameron and others, 1969). Approximately 0.5 μg of lead was taken up in approximately 10 μL of dilute colloidal silica gel, loaded onto a rhenium-ribbon filament, and evaporated to dryness. The filament is then loaded into a solid-source thermal ionization mass spectrometer and heated to 1,150–1,350°C for data acquisition. Analyses by Ken Ludwig (listed as KL in the Analyst column of table 1) were made using a VG Instruments Sector 54, 7-collector mass spectrometer run in "static" mode. Analyses by Robert Vaughn (listed as RV) were run on a single collector, NBS-type 12-inch solid source mass spectrometer described in Gaccetta and Church (1989). Analyses of National Institute for Standards and Technology Standard Reference Material 981 (NIST SRM 981, Common Lead Isotopic Standard) were

used to monitor mass fractionation during mass spectrometry (Cantanzaro and others, 1968; Todt and others, 1996). The lead isotope data have all been corrected for thermal fractionation using the National Bureau of Standards (NBS) SRM-981 common-Pb standard (Catanzaro and others, 1968) and are corrected for mass discrimination of 0.11 ± 0.04 percent per amu. Results are generally accurate, at the 2 sigma level, to within ± 0.1 percent/mass unit or better; analytical errors are reported in table 1.

Results

The analytical data are summarized in table 1. Geologic data are summarized from Nokleberg and others (1996). Site descriptions for most of the samples analyzed are listed therein by Site Number. Standard abbreviations are used for geologic time periods for the age of the host rock and the time of mineralization. Minerals are listed in decreasing order of abundance based on visual analysis of hand specimens.

Mineral abbreviations used in the column marked Mineralogy are:

ang, anglesite; ank, ankerite; asp, arsenopyrite; Au, gold; Ag, silver or mixed silver-bearing minerals; bg, boulangerite; bar, barite; bn, bornite; Bi, bismuth-bearing minerals; cal, calcite; cc, chalcocite; ch, chrysocolla; cn, cinnabar; cp, chalcopyrite; cr, chromite; cs, cerussite; cu, cuprite; cv, covelite; dl, dolomite; ep, epidote; fl, fluorite; gn, galena (GN where a handpicked separate is used for chemical analysis); gt, garnet; hm, hematite; lm, limonite; ma, malachite; mar, marcasite; mly, molybdenite; mt, magnetite; po, pyrrohotite; px, pyroxene; py, pyrite; qz, quartz; REE, rare-earth minerals; rut, rutile; Sb, antimony-bearing minerals; sch, scheelite; si, siderite; sl, sphalerite; Sn, tin-bearing minerals; ss, smithsonite; st, stibnite; stn, stannite; sulfosalts, mixed sulfosalt minerals, tt, tetrahedrite (TT where a handpicked separate is used for chemical analysis); and tu, tourmaline.

Age abbreviations used in the columns marked Geologic Host Age and Mineralization Age are:

Era	Period
Mz Mesozoic	**K** Cretaceous
	J Jurassic
	Ŧ Triassic
Pz Paleozoic	**P** Permian
	IP Pennsylvanian
	M Mississippian
	D Devonian
	S Silurian
	O Ordovician
	Ꞓ Cambrian
pꞒ Precambrian, probably Neoproterozoic(?)	

Subdivisions of periods are designated as early (e), middle (m), and late (l).

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The two Russian co-authors, Nikolai A. Goryachev and Vladimir I. Shpikerman, did not visit all of the deposits or occurrences from which we have reported analytical data. Many geologists have contributed samples for this compilation. To them, we express our thanks for providing samples and field information for each of these mineral occurrences.

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