LEAD ISOTOPE DATA FROM THE
STEWART MINING CAMP*
(104B/1)

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INTRODUCTION

This report presents new galena lead isotope data from ten mineral occurrences in the Stewart area. The results indicate that the formation of these ten varied deposits can be attributed to just two mineralizing events. The two distinct metallogenic epochs are characterized by different base and precious metal suites, thus lead isotope analysis may be a practical aid to commodity-specific exploration programs and to evaluation of mineral showings at an early stage of a property examination.

In 1986, a suite of galena samples, representing ten deposits on eight properties in the Stewart district, was submitted for lead isotope analysis (Figure 2-12-1 and Tables 2-12-1, 2-12-2 and 2-12-3). Comprehensive bibliographies for each of the sampled deposits are available in the British Columbia Mineral Inventory File (MINFILE) and the MINFILE reference number for each deposit is listed in Table 2-12-1. Detailed descriptions of rock types, their distribution and field relationships in the Stewart area are provided in Alldrick (1985) and are simplified in Figure 2-12-1.

PRINCIPLES OF LEAD ISOTOPE
INTERPRETATION

The "lead-lead" or "common lead" method of radiometric dating is based on the accurate measurement of lead isotope abundances (Figure 2-12-2) and on the changing ratios of radiogenic lead isotopes over periods of geologic time (Figure 2-12-3). Galena is used because once it has crystallized, its lead isotopic composition remains constant due to the absence of any radioactive elements in its crystal lattice structure. The reference isotope, ^{204}Pb, is not produced by radioactive decay and so has always been constant in amount (Figure 2-12-2). ^{206}Pb and ^{207}Pb are formed by the radioactive decay of ^{238}U and ^{235}U respectively. ^{235}U has a much shorter half-life [704 million years (Ma)] than ^{238}U (4470 Ma) consequently most of the ^{235}U that was originally present has decayed and the ratio of radiogenic ^{207}Pb to ^{204}Pb has changed little over the past 2000 million years. In contrast, the ratio of radiogenic ^{206}Pb to ^{204}Pb is still increasing relatively rapidly.

Holmes (1946) and Houtermans (1946) first used the exponential radioactive decay law to calculate a curve which corresponded to the evolution or "growth" of the radiogenic lead isotopes with time. The difference in the rate of lead isotope generation from the two uranium parent isotopes is reflected in the progressive flattening of the isotopic lead "growth curve" toward younger ages in Figure 2-12-3. As measurements of lead isotopic ratios accumulated over the next decade, it was noted that the isotopic composition of lead from several conformable ore deposits of various ages were coincident with the Homes-Houtermans growth curve (Stanton and Russell, 1959). By extrapolating the growth curve backward in time

according to the radioactive decay law, it coincides with the lead isotope ratios for iron meteorite fragments from Meteor Crater, Arizona at an indicated age of 4600 Ma. This is similar to ages for meteorites and moon rocks calculated by rhubidium-strontium and uranium-lead methods and the 4600-Ma date is interpreted to be the age of formation of the earth.

The growth curve illustrated in Figure 2-12-3 is accurate as a first approximation for lead isotope ratios from many conformable ore deposits, but at more detailed scales this simple curve does not adequately explain isotopic ratios for lead from most epigenetic ores and some conformable ores. Empirically derived mathematical best fit curves, termed "model curves" or "models", have been proposed by many researchers to explain the small scale deviations from the basic growth curve. The reader is referred to major papers by Armstrong (1968), Stacey and Kramers (1975), Cumming and Richards (1975), Doe and Zartman (1979), Godwin and Sinclair (1982), Andrew, Godwin and Sinclair (1984) and Gulson (1986) for applications of "model curves" to lead isotope data.

ANALYTICAL METHODS

All the lead analysed was extracted from medium to coarse-grained hand-picked galena. Sample preparation and lead isotope analyses were completed by J.E. Gabites in the geochronology laboratory, Department of Geological Sciences, The University of British Columbia. Lead isotope ratios were measured on a Vacuum Generators Isomass 54R solid source mass spectrometer linked to a Hewlett-Packard HP-85 computer. Samples were loaded using phosphoric acid and silica gel.

In-run precision, or machine error, is usually better than 0.01 per cent standard deviation. Repeated measurement of the Broken Hill standard (BHS-UBC1) and systematic analyses of duplicates were used to monitor the analytical precision of the runs. Isotope ratios were normalized to the BHS values of Richards et al. (1981). The minimum variation observed in duplicate analyses is less than 0.05 per cent.

Even under optimum analytical conditions errors arise from fractionation processes which cause relative depletion of the lighter lead isotopes with respect to the heavier ones. Isotopic fractionation is the main source of analytical variations in single filament spectrometers. Another analytical error is associated with the measurement of the low intensity ^{204}Pb spectrometer peak due to the low abundance of this isotope. The slopes of the fractionation error and the ^{204}Pb error are illustrated on each diagram in Figure 2-12-4.

RESULTS

The results of these new galena lead isotope analyses are listed in Tables 2-12-2 and 2-12-3 and plotted as conventional lead isotope

diagrams on Figures 2-12-4A, 4B and 4C. All data reduction for this report has been calculated with the decay constants recommended by the Subcommission on Geochronology of the International Union of Geological Sciences (Steiger and Jäger, 1977).

Table 2-12-1 lists the deposit name, location, host lithology, deposit type and the British Columbia Mineral Inventory File (MIN-FILE) number. Table 2-12-2 presents galena lead isotope data from six deposits on four properties that plot as a discrete cluster, marked Cluster 1, on Figure 2-12-4A, 4B and 4C. Table 2-12-3 lists galena lead isotope data from four deposits that plot as a second discrete cluster, marked Cluster 2, on Figure 2-12-4A, 4B and 4C. To simplify the plots and improve clarity, only the ten averaged values indicated on Tables 2-12-2 and 2-12-3 have been plotted on Figure 2-12-4.

INTERPRETATION

The following discussion is based mainly on relationships between uranogenic lead (^{206}Pb, ^{207}Pb) and thoriogenic lead (^{208}Pb) shown on Figures 2-12-4A and 2-12-4B. The plot in Figure 2-12-4C is primarily used to analyse the effects of ^{204}Pb error, which is small for this data set; fractionation error is also minimal.

"Common lead" isotope data can yield crude absolute age determinations if a suitable model curve is available for interpretation. A model may also provide indications about the source of elemental lead in an ore deposit. Development of such a model requires a large database from similar rocks and sulphides which must be assembled before meaningful absolute age determinations can be attempted. There is not enough spread in the Stewart data points to construct an empirical model curve by graphical means. However, smaller lead isotope data sets are useful for indicating relative age relationships between deposits, and between deposits and their host rocks. The interpretation of relative, nonabsolute age relationships from lead isotope data is known as "fingerprinting".

Fingerprint interpretation of lead isotope data is a simple powerful tool when combined with other geological data. The following six interpretations are derived from the data presented in Figures 2-12-1, 2-12-3 and 2-12-4B.

(1) On Figure 2-12-3, the position of the field of Figure 2-12-4B indicates that all the deposits sampled in this study are Phanerozoic.

(2) Comparing the relative positions of the two data clusters of Figure 2-12-4B with the progressive evolution of lead isotope ratios shown in Figure 2-12-3 suggests that the galena of the deposits in Cluster 2 might be significantly younger than the galena of Cluster 1 deposits. This relative age relationship is consistent with interpretations based on geological evidence and can be confirmed mathematically by applying the radioactive decay law.

(3) The two tight clusters of data shown on Figure 2-12-4B clearly define two separate metallogenic events in the Stewart area.

(4) The tightness of the two data clusters indicates that each of the two ore-forming events was a short-lived episode in geologic time.

(5) Both clusters of data represent deposits that are distributed over a 30-kilometre strike length, thus the two metallogenic processes that formed these deposits were both regional phenomena.

(6) Although the Indian mine and the Silbak Premier mine are less than 2 kilometres apart, the data indicate that these deposits are not genetically related and that they formed at significantly different times, with the Indian mine being the younger of the two.

Alldrick (1985) and Alldrick et al. (this volume) argued that the two ore-forming episodes were not closely related genetic pro-

cesses. Specifically, Cluster 1 deposits formed cogenetically with calc-alkaline Hazelton Group volcanic rocks of the Stikinia terrane about 190 million years ago. The Cluster 2 deposits are epigenetic veins related to Eocene intrusion of dominantly granodioritic plutons that were generated by subduction processes.

The data clusters of Figure 2-12-4 can be used to generally support the interpretation of Jurassic and Tertiary metallogenic epochs, yet also indicate that the mineralizing events are genetically distinct. If an age can be assigned to one of the two data clusters based on geological or other isotopic evidence, an approximate elapsed time between the two data clusters can be calculated using the radioactive decay law. When a date of 48 Ma is assigned to the group mean of Cluster 2, the group mean of Cluster 1 yields a calculated age of 210 Ma. This latter date is close to the 190-Ma age interpreted for the Cluster 1 metallogenic event by Alldrick et al. (this volume). This calculation also yields a ratio of the parent ^{238}U to the reference ^{204}Pb isotope of 14.0, known as the μ value. This value for μ is unnaturally high (μ values for all model curves lie between 8.2 and 12.2), and therefore indicates that the galena lead in the deposits of Cluster 2 is not simply remobilized or evolved from the same lead source as Cluster 1 deposits.

When these interpretations are combined with other studies, they provide corroborative support for many established interpretations, raise questions about some earlier theories, and suggest an application for systematic lead isotope analysis in exploration programs in the Stewart area.

The data indicate that the ore at the Indian mine is cogenetic with mineralization at the Porter Idaho mine, the Bayview prospect and the Jarvis vein. The Porter Idaho mine and Bayview prospect were interpreted as Eocene age deposits based on field relationships (Alldrick, 1985 and Alldrick and Kenyon, 1984) and on potassium-argon dates from associated intrusive rocks (Smith, 1977). This interpretation is further supported by a new potassium-argon date of 42.7 Ma from the altered host rocks at the Indian mine (Alldrick, et al., this volume). The indicated Middle Eocene age of these mineral deposits coincides with the age of many intrusive rocks along the eastern margin of the Coast Plutonic Complex (Carter, 1981). Significantly, this epoch also coincides with the age of many major porphyry molybdenum deposits, with peripheral high-grade silver veins and disseminations, that are also distributed along the eastern margin of the Coast Plutonic Complex, for example, Kitsault (MI 103P-120), Ajax (MI 103P-223), Tidewater (MI 103P-111), Molly Mack (MI 103P-228), Roundy Creek (MI 103P-234), Bell Moly (MI 103P-113), Valley Ridge (MI 103P-231), Snafu (MI 103P-232), Kay (MI 103P-225) and others (Carter, 1981). Woodcock and Hollister (1978) concluded that this zone was the locus for a major metallogenic province of molybdenum ($\pm$ tungsten) porphyry deposits throughout North America. In the Stewart region, formation of these deposits took place during a restricted interval of Middle Eocene time, 48-43 million years ago.

Alldrick (1985, page 337) concluded that the Indian mine ores formed at the same time as oreshoots at the nearby Silbak Premier mine, on the basis of textural and mineralogical similarities between the coarse-grained galena-sphalerite ore found at the Indian mine and in ore zones at the deepest levels of the Silbak Premier mine, termed the Northern Lights or Premier Border zone (MI 104B-53). The single lead isotope determination for the Silbak Premier mine comes from a sample near the upper workings, 500 metres above the Northern Lights zone. The deep level galena-sphalerite ores of the Silbak Premier may be genetically related to the overlying oreshoots (Cluster 1), or they may be younger, superimposed sulphide deposits genetically related to Indian mine mineralization (Cluster 2).

The deposits of Cluster 1 and similar deposits in the Stewart district are either gold-silver-pyrrhotite veins, such as the Scottie
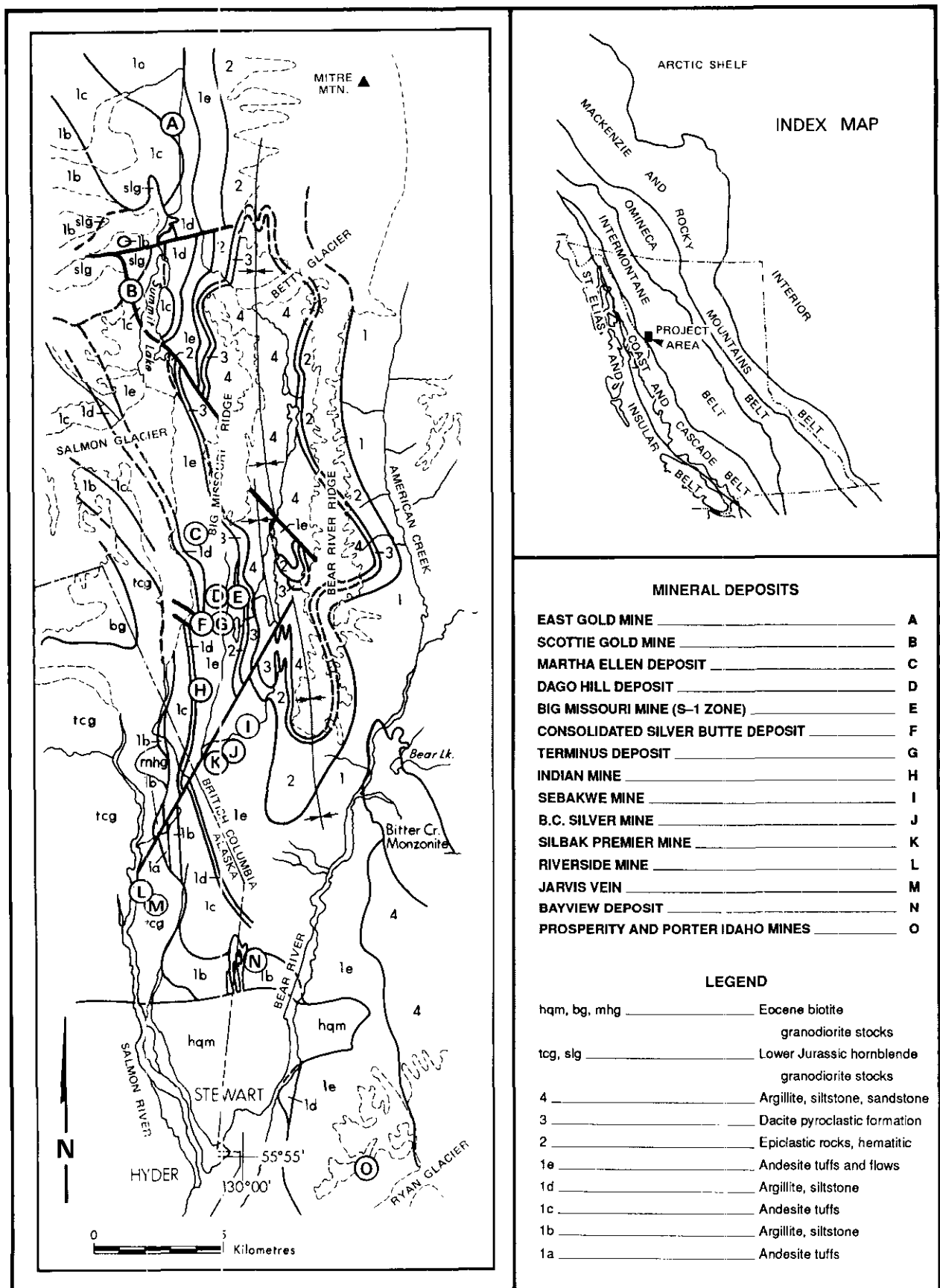
Figure 2-12-1. Geology and mineral deposits of the Stewart area (from Alldrick, 1985).

INDEX MAP

ARCTIC SHELF

MACKENZIE AND ROCKY
OMINECA
INTERMONTANE
MOUNTAINS
ST. ELIAS, AND
INTERIOR
COAST AND
INSULAR
CASCADE BELT
BELT
BELT
BELT
PROJECT AREA

MINERAL DEPOSITS

EAST GOLD MINE	A
SCOTTIE GOLD MINE	B
MARTHA ELLEN DEPOSIT	C
DAGO HILL DEPOSIT	D
BIG MISSOURI MINE (S–1 ZONE)	E
CONSOLIDATED SILVER BUTTE DEPOSIT	F
TERMINUS DEPOSIT	G
INDIAN MINE	H
SEBAKWE MINE	I
B.C. SILVER MINE	J
SILBAK PREMIER MINE	K
RIVERSIDE MINE	L
JARVIS VEIN	M
BAYVIEW DEPOSIT	N
PROSPERITY AND PORTER IDAHO MINES	O

LEGEND

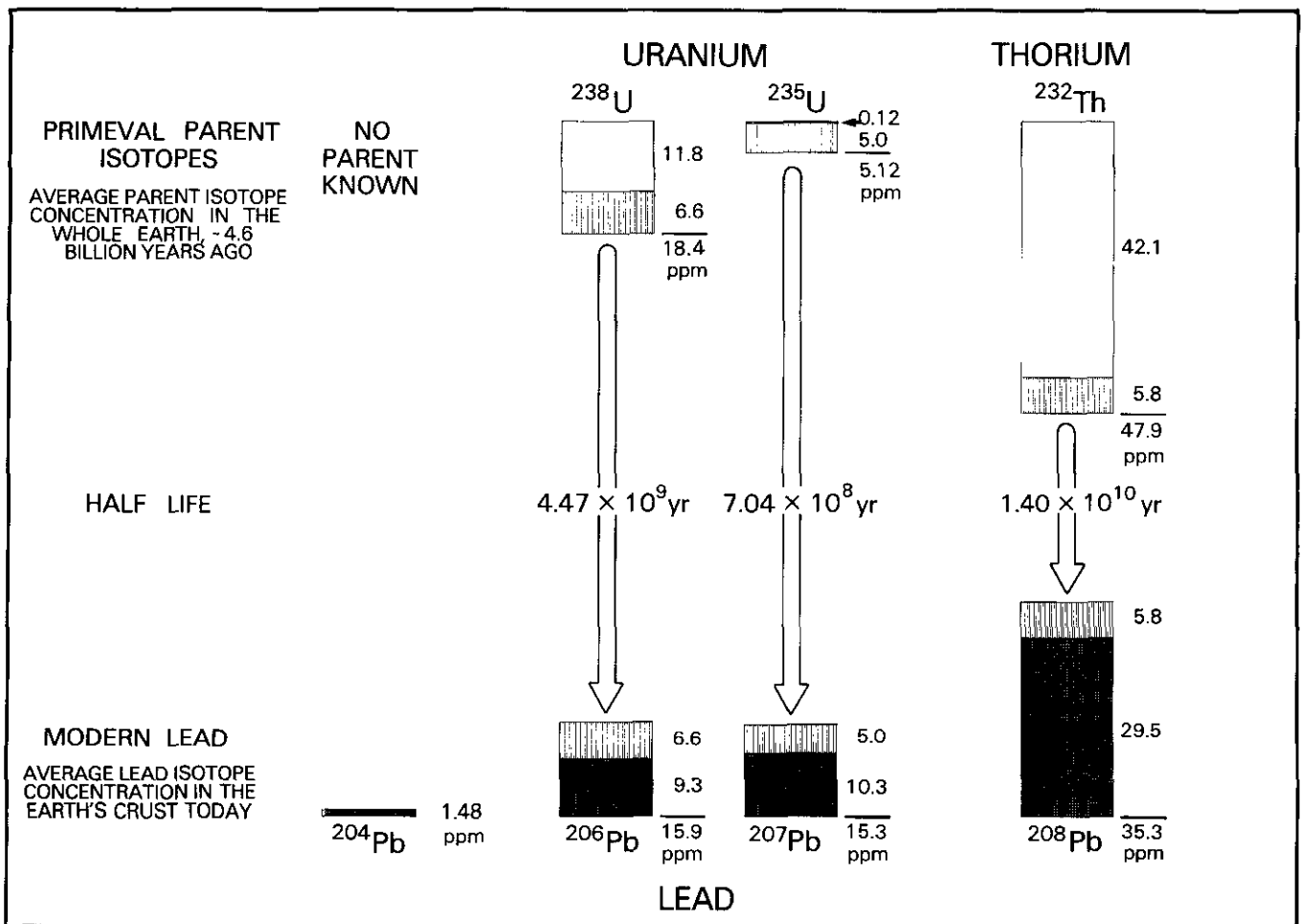|	
hqm, bg, mhg	Eocene biotite granodiorite stocks
tcg, slg	Lower Jurassic hornblende granodiorite stocks
4	Argillite, siltstone, sandstone
3	Dacite pyroclastic formation
2	Epiclastic rocks, hematitic
1e	Andesite tuffs and flows
1d	Argillite, siltstone
1c	Andesite tuffs
1b	Argillite, siltstone
1a	Andesite tuffs

Figure 2-12-2. Isotopic relationships between uranium, thorium and lead in the earth's crust. Dark grey = primeval lead; light grey = uranium and thorium decayed to radiogenic lead during 4.6 billion years; white = radioactive parent isotopes that still remain [modified from Cannon *et al.* (1961), Tatsumoto *et al.* (1973) and Steiger and Jager (1977)].

TABLE 2-12-1
DEPOSIT LOCATION, HOST UNIT, DEPOSIT TYPE AND MINFILE NUMBER

BC Lead File Deposit Number	Deposit Name	NTS Number (MINFILE Number)	Lat. N Long. W (degrees)	Lithology	Deposit Type
30415	Big Missouri	104B/01E (104B-046)	56.13 130.03	Unuk River: altered andesite tuff	Vein
30492	Prosperity-Porter Idaho	103P/13W (104B-089)	55.91 129.94	Unuk River: dacitic and andesite tuff	Vein in shear
30493	Scottie Gold	104B/01E (104B-074)	56.22 130.09	Unuk River: andesite tuff	Mesothermal Au-Po vein
30494	Silbak Premier	104B/01E (104B-054)	56.05 130.01	Unuk River: altered andesite tuff	Epithermal vein
30495	Consolidated Silver Butte	104B/01E (104B-095)	56.11 130.03	Unuk River: altered andesite tuff	Epithermal Au-Ag vein
30765	Bayview	103P/13W (103P-051)	55.96 129.98	Unuk River: hornfelsed argillite	Vein
30871	Jarvis	1030/16E (1030-024)USA	55.99 130.07	Texas Creek (HB) granodiorite	Vein
30939	Indian (New Indian)	104B/01E (104B-031)	56.08 130.03	Unuk River: andesitic and lapilli tuff	Vein in shear

TABLE 2-12-2

LEAD ISOTOPE DATA FOR CLUSTER 1 DEPOSITS

Plotted Values on Figure 2-12-4	Sample No.	Deposit/Sample Name	Quality	$\frac{206_{Pb}}{204_{Pb}}$ % error	$\frac{207_{Pb}}{204_{Pb}}$ % error	$\frac{208_{Pb}}{204_{Pb}}$ % error	$\frac{206_{Pb}}{207_{Pb}}$ % error	$\frac{206_{Pb}}{208_{Pb}}$ % error
	30415-006	Big Missouri (Creek), SR-114	Good	18.820 ± 0.02	15.615 ± 0.02	38.456 ± 0.02	1.20526 ± 0.01	0.489399 ± 0.01
	30415-007	Big Missouri (Terminus), SR-169	Good	18.823 ± 0.02	15.609 ± 0.02	38.435 ± 0.03	1.20388 ± 0.01	0.489729 ± 0.02
	30415-008	Big Missouri (Martha Ellen), 1	Good	18.824 ± 0.03	15.610 ± 0.02	38.458 ± 0.03	1.20587 ± 0.01	0.489467 ± 0.01
	30415-008R	Big Missouri (Martha Ellen), 1	Good	18.822 ± 0.01	15.611 ± 0.01	38.453 ± 0.02	1.20571 ± 0.01	0.489475 ± 0.02
	30415-008A	Big Missouri (Martha Ellen N = 2)	Good	18.823 ± 0.00	15.611 ± 0.00	38.456 ± 0.01	1.20579 ± 0.00	0.489471 ± 0.00
*	30415-Avg	Big Missouri (N = 3)	Good	18.822 ± 0.02	15.612 ± 0.01	38.449 ± 0.02	1.20564 ± 0.00	0.489533 ± 0.00
*	30493-001	Scottie Gold, SG-8	Good	18.804 ± 0.02	15.608 ± 0.01	38.426 ± 0.02	1.20472 ± 0.02	0.489352 ± 0.01
*	30494-007	Silbak Premier, SR-45	Good	18.825 ± 0.01	15.611 ± 0.01	38.421 ± 0.02	1.20589 ± 0.01	0.489966 ± 0.01
	30495-001	Consol. Silver Butte, SR-168	Good	18.828 ± 0.02	15.619 ± 0.02	38.474 ± 0.02	1.20548 ± 0.01	0.489361 ± 0.01
	30495-001D	Consol. Silver Butte, SR-168	Fair	18.812 ± 0.04	15.604 ± 0.04	38.432 ± 0.04	1.20545 ± 0.01	0.489473 ± 0.01
*	30495-001A	Consolidated Silver Butte (N = 2)	Good	18.820 ± 0.02	15.612 ± 0.02	38.453 ± 0.06	1.20547 ± 0.00	0.489416 ± 0.01
*	Jurass-AVG	AVG of Jurassic Group		18.818 ± 0.02	15.611 ± 0.00	38.437 ± 0.03	1.20544 ± 0.00	0.489567 ± 0.00

D = duplicate (new chemistry).
R = sample repeat; repeat analysis (same chemistry).
A = Sample average.
AVG = deposit average.

Errors on all averages are %2σ.
Broken Hill Standard (Richard, 1981): 6/4 16.004 (.001), 7/4 15.390 (.007), 8/4 35.651 (.017).

TABLE 2-12-3
LEAD ISOTOPE DATA FOR CLUSTER 2 DEPOSITS

Plotted Values on Figure 2-12-4	Sample No.	Deposit/Sample Name	Quality	$\frac{206_{Pb}}{204_{Pb}}$ % error	$\frac{207_{Pb}}{204_{Pb}}$ % error	$\frac{208_{Pb}}{204_{Pb}}$ % error	$\frac{206_{Pb}}{207_{Pb}}$ % error	$\frac{206_{Pb}}{208_{Pb}}$ % error
	30492-001	Prosperity-Porter Idaho, PI-7	Good	19.130 ± 0.03	15.627 ± 0.02	38.644 ± 0.03	1.22418 ± 0.01	0.495027 ± 0.01
	30492-002	Prosperity-Porter Idaho, PI-10	Good	19.116 ± 0.02	15.624 ± 0.01	38.616 ± 0.02	1.22351 ± 0.01	0.495020 ± 0.01
	30492-003	Prosperity-Porter Idaho, PI-11	Good	19.114 ± 0.02	15.610 ± 0.01	38.589 ± 0.03	1.22448 ± 0.01	0.495317 ± 0.02
	30492-003R	Prosperity-Porter Idaho, PI-11	Good	19.122 ± 0.02	15.619 ± 0.01	38.614 ± 0.02	1.22433 ± 0.01	0.495214 ± 0.01
	30492-003A	Prosperity-Porter Idaho (N=2)	Good	19.118 ± 0.01	15.615 ± 0.01	38.602 ± 0.03	1.22441 ± 0.00	0.495266 ± 0.01
•	30492-AVG	Prosperity-Porter Idaho (N=3)	Good	19.121 ± 0.02	15.622 ± 0.01	38.621 ± 0.04	1.22403 ± 0.00	0.495104 ± 0.00
	30765-002	Bayview, Pit 3/1	Good	19.153 ± 0.01	15.616 ± 0.01	38.608 ± 0.01	1.22651 ± 0.01	0.496086 ± 0.00
	30765-003R	Bayview, Pit 3/2	Good	19.151 ± 0.01	15.623 ± 0.01	38.623 ± 0.02	1.22575 ± 0.01	0.495707 ± 0.01
	30765-004	Bayview, Pit 3/3	Good	19.152 ± 0.01	15.622 ± 0.00	38.633 ± 0.01	1.22594 ± 0.01	0.495752 ± 0.01
*	30765-AVG	Bayview	Good	19.152 ± 0.00	15.620 ± 0.01	38.621 ± 0.02	1.22607 ± 0.00	0.495848 ± 0.00
	30871-001	Jarvis, JA-1	Good	19.164 ± 0.03	15.607 ± 0.02	38.579 ± 0.04	1.22792 ± 0.02	0.496755 ± 0.03
	30871-002	Jarvis, JA-7	Good	19.158 ± 0.01	15.625 ± 0.01	38.616 ± 0.01	1.22614 ± 0.01	0.496131 ± 0.00
	30871-003	Jarvis, JA-11	Good	19.174 ± 0.02	15.635 ± 0.01	38.656 ± 0.02	1.22631 ± 0.01	0.496011 ± 0.02
*	30871-AVG	Jarvis (N=3)	Good	19.165 ± 0.02	15.622 ± 0.03	38.617 ± 0.08	1.22679 ± 0.00	0.494299 ± 0.00
	30939-001	Indian (New Indian), IM-1	Good	19.150 ± 0.02	15.625 ± 0.01	38.665 ± 0.03	1.22556 ± 0.01	0.495273 ± 0.02
	30939-002	Indian (New Indian), IM=1A	Good	19.159 ± 0.02	15.621 ± 0.02	38.650 ± 0.02	1.22644 ± 0.01	0.495696 ± 0.01
*	30939-AVG	Indian (New Indian, N=2)	Good	19.155 ± 0.01	15.623 ± 0.01	38.658 ± 0.02	1.22600 ± 0.00	0.495485 ± 0.00
*	Tertiar-AVG	AVG of Tertiary Group	Good	19.148 ± 0.04	15.622 ± 0.00	38.629 ± 0.04	1.22572 ± 0.00	0.495684 ± 0.00

D = duplicate (new chemistry).

R = sample repeat; repeat analysis (same chemistry).

A = Sample average.

AVG = deposit average.

Errors on all averages are %2σ.

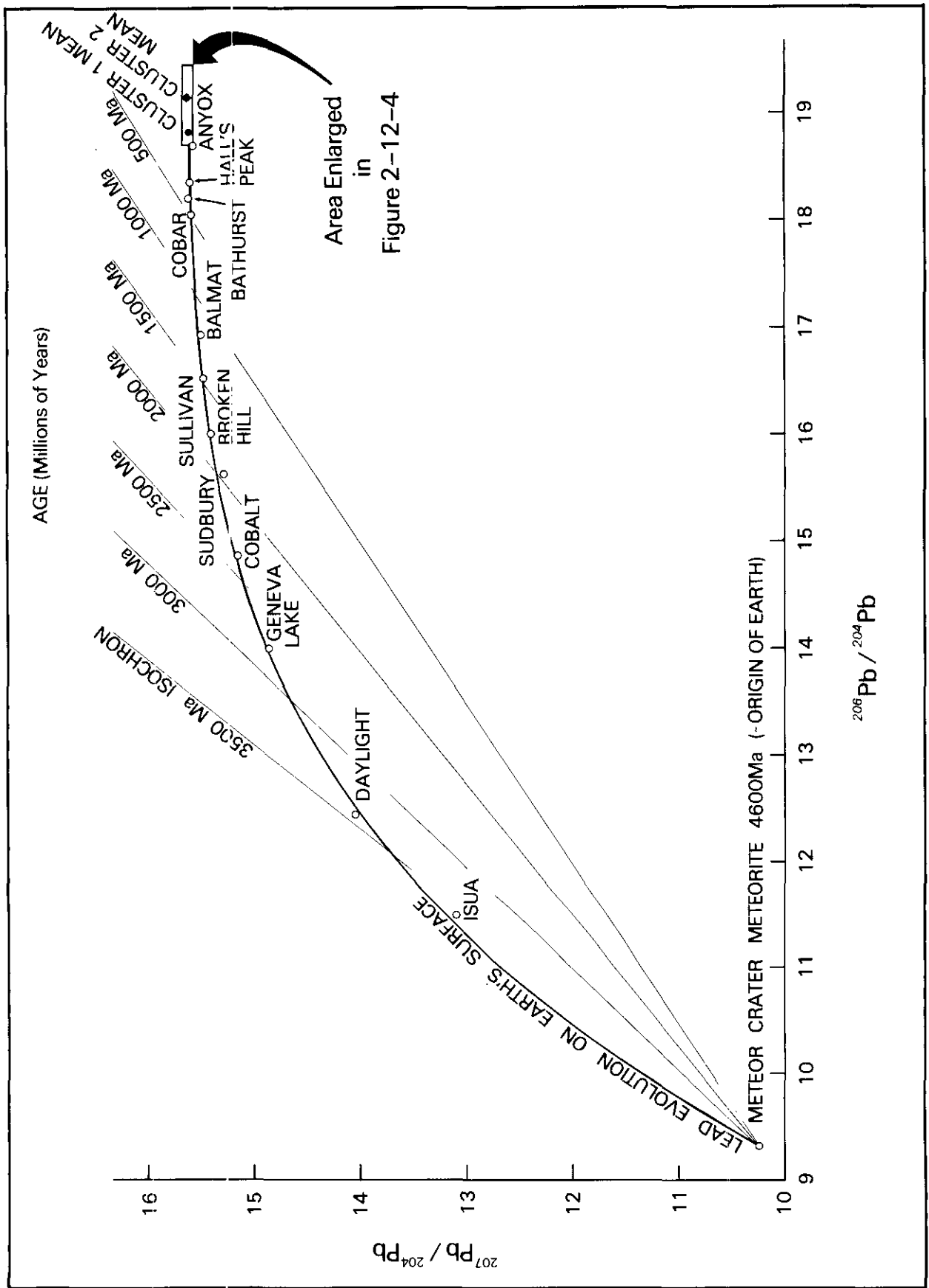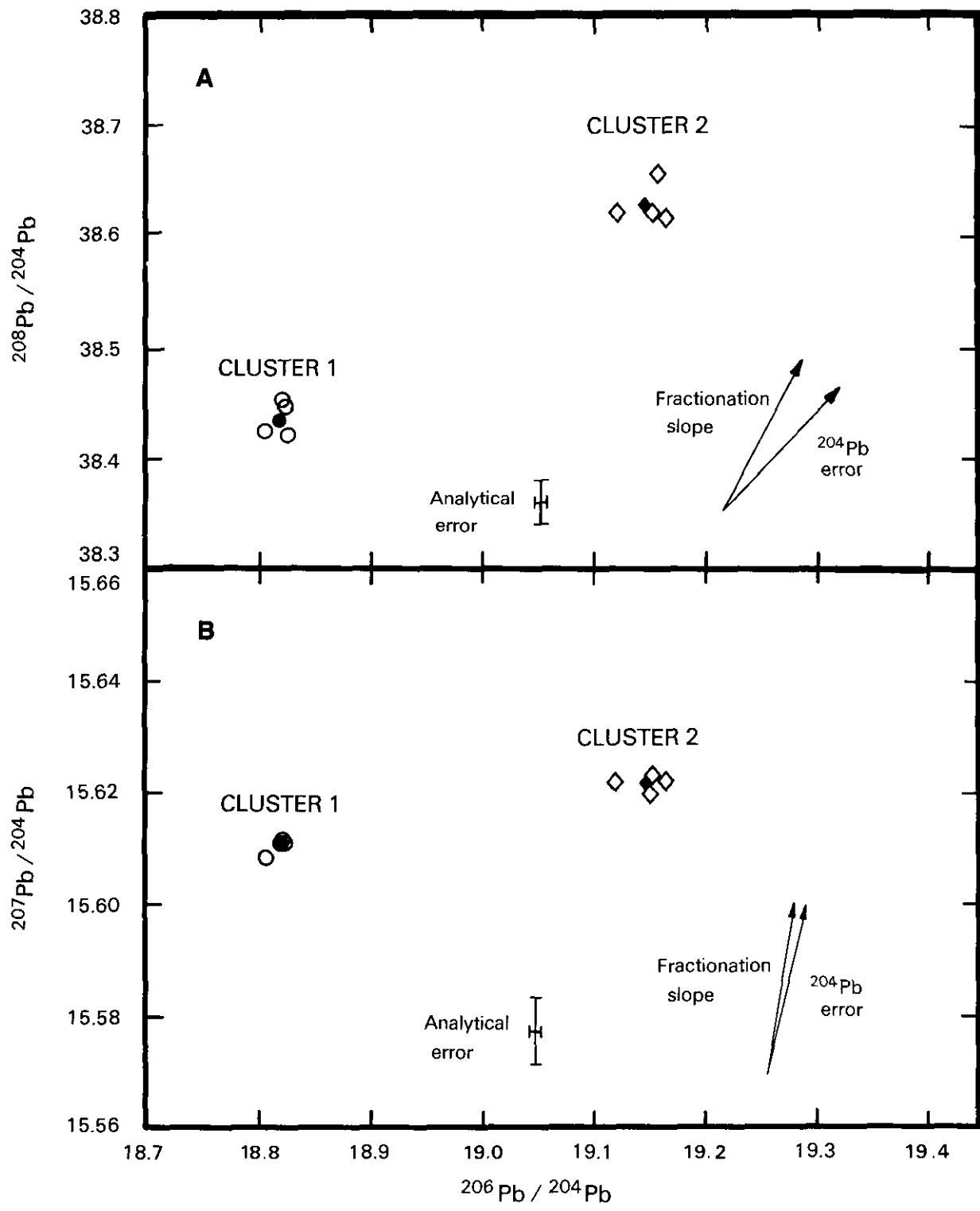Broken Hill Standard (Richard, 1981): 6/4 16.004 (.001), 7/4 15.390 (.007), 8/4 35.651 (.017).

Figure 2-12-3. Growth curve for lead isotope evolution showing distribution of Cluster 1 and Cluster 2 data sets [modified from Armstrong (1968) and Moorbath (1985); data from Cumming and Richards (1975), Alldrick (1986) and this study].
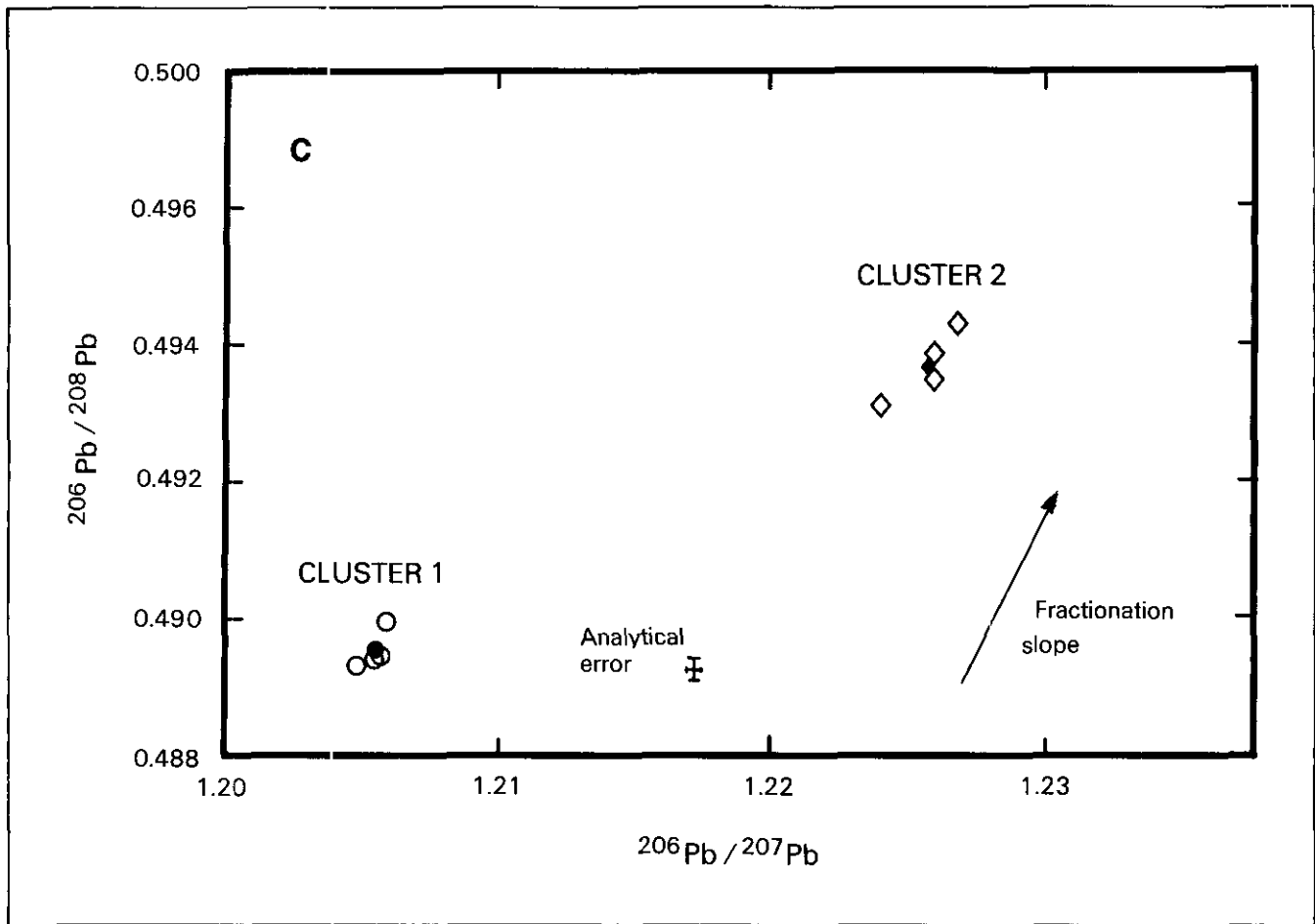
Figure 2-12-4. Plots of averaged lead isotopic ratios for deposits located on Figure 2-12-1 and listed in Tables 2-12-2 and 2-12-3. ○ = deposits with Jurassic lead signature, ◇ = deposits with Tertiary lead signature. Closed symbols represent group means. Analytical error shown is 2σ from 46 analyses of Broken Hill galena standard.

Gold mine, or gold-silver-lead-zinc-copper deposits such as the Silbak Premier mine. In contrast, deposits of Cluster 2 are silver-lead-zinc veins characterized by high silver grades and by spatially associated molybdenum and/or tungsten occurrences. In small outcrop or trench exposures the structural, textural and mineralogical differences between the deposits are not always evident. For example, samples from the Creek zone at the Big Missouri property and from the Number 3 trench at the Bayview prospect are mineralogically similar in hand sample. As Figure 2-12-4B shows, the lead isotope ratios clearly distinguish the different ore-forming episodes that produced the deposits.

The same indications might be achieved by assays; sulphide-rich grab samples show values up to 18 ppm gold and 323 ppm silver at the Creek zone while a grab sample from the Bayview trench assayed 1 ppm gold and 3472 ppm silver. Unfortunately assays of a few fist-sized grab samples are unreliable indicators of the overall gold and silver grades of the entire mineralized zone, whereas two or three lead isotope ratios from galena crystals would be representative for the deposits. A lead isotope analysis from galena in a small exposure or in a weakly mineralized vein would indicate whether the mineral occurrence was related to the earlier gold-silver(-base metal) event or to the later silver-lead-zinc(-molybdenum-tungsten) mineralizing episode. This distinction might govern the urgency, intensity or necessity for further exploration work.

CONCLUSIONS

Lead isotope data from the Stewart mining camp do not provide absolute age dates for the formation of mineral deposits, but the relative distributions of data are consistent with absolute dates determined in other studies. The genesis of ten varied mineral deposits can be attributed to just two mineralizing events. The formation of more than one hundred other mineral occurrences in the district may be related to these same two ore-forming episodes. Both metallogenic epochs were brief, regional-scale phenomena. Deposits from the younger mineralizing episode may be emplaced adjacent to older deposits.

In the Stewart area, routine lead isotope analysis would be a practical aid for exploration programs focused on specific commodities. The method is an effective technique for evaluating the commodity potential of a small mineral showing, or for setting exploration priorities on properties that host several varied mineral occurrences.

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REFERENCES

Alldrick, D.J. (1985): Stratigraphy and Petrology of the Stewart Mining Camp (104B/1), *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1984, Paper 1985-1, pages 316-341.

———— (1986): Stratigraphy and Structure in the Anyox Area (103P/5), *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1985, Paper 1986-1, pages 211-216.

Alldrick, D.J. and Kenyon, J.M. (1984): The Prosperity/Porter Idaho Silver Deposits (103P/0), *B.C. Ministry of Energy, Mines and Petroleum Resources*, Geological Fieldwork, 1983, Paper 1984-1, pages 165-172.

Andrew, A., Godwin, C.I. and Sinclair, A.J. (1984): Mixing Line Isochrons: A New Interpretation of Galena Lead Isotope Data from Southeastern British Columbia, *Economic Geology*, Volume 79, pages 919-932.

Armstrong, R.L. (1968): A Model for the Evolution of Strontium and Lead Isotopes in a Dynamic Earth, *Review of Geophysics*, Volume 6, pages 175-199.

Cannon, R.S., Pierce, A.P. and Antweiler, J.C. (1971): Suggested Uses of Lead Isotopes in Exploration, *in Canadian Institute of Mining and Metallurgy*, Special Volume 11, Boyle, R.W., editor, pages 457-463.

Carter, N.C. (1981): Porphyry Copper and Molybdenum Deposits of West-Central British Columbia, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 64.

Cumming, G.L. and Richards, J.R. (1975): Ore Lead Isotope Ratios in a Continuously Changing Earth, *Earth and Planetary Science Letters*, Volume 28, pages 155-171.

Doe, B.R. and Zartman, R.E. (1979): Plumbotectonics, the Phanerozoic, *in* Geochemistry of Hydrothermal Ore Deposits, Barnes, H.L., editor, *John Wiley and Sons*, New York, pages 22-70.

Faure, G. (1977): Principles of Isotope Geology, *John Wiley and Sons*, New York, 464 pages.

Godwin, C.I. and Sinclair, A.J. (1982): Average Lead Isotope Growth Curves for Shale-Hosted Lead-Zinc Deposits, Cana-

dian Cordillera, *Economic Geology*, Volume 77, pages 675-690.

Gulson, B.L. (1986): *Lead Isotopes in Mineral Exploration*, Elsevier, Amsterdam, 258 pages.

Harper, C.T., editor, (1973): Geochronology: Radiometric Dating of Rocks and Minerals, *Dowden, Hutchinson and Ross*, Stroudsberg, 469 pages.

Holmes, A. (1946): An Estimate of the Age of the Earth, *Nature*, Volume 157, pages 681-684.

Houtermans, F.G. (1946): The Isotopic Abundances in Natural Lead and the Age of Uranium, *Naturwissenschaften*, Volume 33, pages 185-186.

Köppel, V. and Grunenfelder, M. (1979): Isotope Geochemistry of Lead, *in* Lectures in Isotope Geology, E. Jäger and J.C. Hunziker, editors, *Springer-Verlag*, Berlin, pages 134-153.

Moorbath, S. (1985): The Age of the Earth and the Oldest Rocks, *Geology Today*, Volume 1, pages 75-79.

Richards, J.R., Fletcher, I.R. and Blockley, J.G. (1981): Pilbara Galenas — Precise Isotopic Assay of the Oldest Australian Leads, *Mineralium Deposita*, Volume 16, pages 7-30.

Russell, R.D. and Farquhar, R.M. (1960): Lead Isotopes in Geology, *Interscience*, New York, 243 pages.

Sillitoe, R.H. (1973): The Tops and Bottoms of Porphyry Copper Deposits, *Economic Geology*, Volume 68, pages 799-815.

Smith, J.G. (1977): Geology of the Ketchikan D-1 and Bradfield Canal A-1 Quadrangles, Southeastern Alaska, *United States Geological Survey*, Bulletin 1425, 49 pages.

Stacey, J.S. and Kramers, J.D. (1975): Approximation of Terrestrial Lead Isotope Evolution by a Two-Stage Model, *Earth and Planetary Science Letters*, Volume 26, pages 207-221.

Stanton, R.L. and Russell, R.D. (1959): Anomalous Leads and the Emplacement of Lead Sulphide Ores, *Economic Geology*, Volume 54, pages 588-607.

Steiger, R.H. and Jager, E. (1977): Subcommission on Geochronology — Convention on the Use of Decay Constants in Geo- and Cosmochronology, *Earth Planetary Science Letters*, Volume 36, pages 359-362.

Tatsumoto, M., Knight, T.J. and Allegre, C.J. (1973): Time Differences in the Formation of Meteorites as Determined from the Ratio of Lead-207 to Lead-206, *Science*, Volume 180, pages 1279-1283.

Woodcock, J.R. and Hollister, V.F. (1978): Porphyry Molybdenite Deposits of the North American Cordillera, *Minerals Science Engineering*, Volume 10, pages 3-18.