PRELIMINARY EXAMINATION OF GOLD METALLOGENY IN THE INSULAR BELT OF THE CANADIAN CORDILLERA USING GALENA-LEAD ISOTOPE ANALYSES

By A. Andrew, C.I. Godwin, and A.J. Sinclair
Department of Geological Sciences
University of British Columbia

ABSTRACT

Lead isotope data from quartz-gold vein deposits and volcanogenic and related deposits in the Insular Belt group fall in four distinct clusters on Pb-Pb plots. Each cluster corresponds to a specific deposit type and host rock category. Two parallel evolutionary trends in the lead isotopic composition exist: (1) Sicker-hosted volcanogenic deposits to Sicker-hosted veins, and (2) Karmutsen and Bonanza-hosted volcanogenic or paramagmatic deposits to Karmutsen and Bonanza-hosted veins. The trends indicate a genetic relationship between host rock and isotopic composition. These observations favour a host rock source for the lead in vein deposits and, by association, a comparable source for gold. Plutonic or abyssal direct sources of metals are not consistent with the lead isotopic data.

We suggest that the gold was extracted from the country rock, concentrated as veins by hydrothermal activity related to Tertiary plutons. Vein deposits are isotopically distinct from volcanogenic and related deposits, providing a model for distinguishing syngenetic from epigenetic deposits in a general way. Karmutsen and Bonanza-hosted deposits are more depleted in ^{207}Pb than similar deposits in Sicker Group rocks, indicating significantly different sources for volcanic components of these two important rock units.

INTRODUCTION

Galena-lead isotope data from mineral deposits in British Columbia have been compiled at the University of British Columbia since 1978 as part of a systematic study of galena-lead isotopes applied to metallogeny in the Canadian Cordillera. One aspect of that data considered here concerns isotopic compositions of lead from volcanogenic and related deposits and quartz-gold veins in the Insular Belt, as they relate to the metallogeny of gold-bearing deposits.

All the data used in this study are listed in Table 1. Information regarding the geological setting, mineral associations, and deposit type was extracted from MINDEP and MINFILE computer files of mineral deposits, annual reports of the British Columbia Ministry of Energy, Mines and Petroleum Resources, and assessment reports submitted to the British Columbia government. The appendix describes the 18 deposits used in this

TABLE 1. LEAD ISOTOPE ANALYSES ON GALENA FROM MINERAL DEPOSITS

Insular Belt, B.C.

Sample Number	Deposit Name	Map Name	Lat° North	Long° West	Lead Isotope Data (relative 1 S error as %) $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Cluster 1: Pennsylvanian - Permian							
G79CL -001	Cowichan Lake	CL	48.7	124.3	18.646(.03)	15.581(.05)	38.276(.10)
G79CL -002	Cowichan Lake	CL	48.7	124.3	18.666(.02)	15.589(.07)	38.396(.10)
G79CL -003	Cowichan Lake	CL	48.7	124.3	18.702(.07)	15.546(.10)	38.086(.30)
*average for Cowichan Lake					18.671(.04)	15.572(.07)	38.252(.16)
*G79IC -001	Iron Clad	IC	48.85	123.68	18.682(.08)	15.581(.07)	38.304(.12)
G79LN -001	Lenora	LN	48.87	123.78	18.534(.04)	15.538(.09)	38.216(.04)
G79LN -002	Lenora	LN	48.87	123.78	18.562(.08)	15.572(.08)	38.23 (.09)
*average for Lenora					18.548(.06)	15.555(.08)	38.223(.06)
*G79TY -001	Tyee	TY	48.87	123.78	18.558(.08)	15.577(.07)	38.123(.11)
G79WM -001	Western: Myra	WM	49.57	125.59	18.506(.06)	15.579(.04)	38.186(.07)
G79WM -002	Western: Myra 2	WM	49.57	125.59	18.488(.07)	15.554(.07)	38.089(.06)
G79WM -003	Western	WM	49.57	125.59	18.484(.06)	15.551(.09)	38.115(.03)
*average for Western					18.493(.06)	15.561(.07)	38.130(.05)
Average for Cluster 1 (n=5)					[18.595(.06)]	[15.569(.07)]	[38.206(.10)]
Standard deviation = S					0.081	0.011	0.079
Standard error = $Sn^{-\frac{1}{2}}$					0.036	0.005	0.035
Cluster 2: Upper Triassic - Jurassic							
*30335 -001	Nutcracker	335	49.75	124.59	18.609(.07)	15.521(.09)	38.048(.10)
*30366 -001	Bon	366	50.26	126.67	18.587(.06)	15.526(.04)	38.086(.10)
30314 -001	Starlight	314	49.02	124.71	18.592(.07)	15.562(.09)	38.196(.05)
Average for Cluster 2 (n=2)					[18.598(.07)]	[15.524(.07)]	[38.067(.08)]
Standard deviation = S					0.016	0.004	0.027
Standard error = $Sn^{-\frac{1}{2}}$					0.011	0.003	0.019
Cluster 3: Tertiary							
30317 -001	Lone Star -ReyOro	317	50.02	126.79	18.940(.08)	15.569(.03)	38.445(.07)
30317 -001	Lone Star -ReyOro	317	50.02	126.79	18.950(.10)	15.571(.06)	38.378(.03)
*average for Lone Star-ReyOro					18.945(.09)	15.57 (.05)	38.411(.05)
*30318 -001	White Star	318	50.03	126.81	18.867(.10)	15.499(.04)	38.245(.05)
*30320 -001	Peerless	320	50.04	126.84	18.986(.06)	15.56 (.10)	38.453(.08)
*30334 -001	Lucky Strike	334	50.06	126.84	18.827(.05)	15.532(.03)	38.405(.09)
*30349 -001	Privateer	349	50.03	126.81	19.011(.08)	15.581(.09)	38.505(.06)
G79AB -001	Alpha and Beta	AB	48.73	124.09	18.882(.03)	15.581(.05)	38.406(.07)
Average for Cluster 3 (n=5)					[18.926(.07)]	[15.548(.06)]	[38.411(.05)]
Standard deviation = S					0.078	0.033	0.099
Standard error mean = $Sn^{-\frac{1}{2}}$					0.035	0.015	0.044

* Asterisk denotes analysis used in calcualtion of averages.

TABLE 1 (Continued)

Sample Number	Deposit Name	Map Name	Lat° North	Long° West	Lead Isotope Data (relative 1 S error as %) $^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Cluster 4: Tertiary?							
*30313 -001	Golden Eagle	313	49.11	124.59	19.007(.08)	15.621(.07)	38.577(.12)
*30315 -001	Victoria	315	49.18	124.66	18.828(.04)	15.646(.04)	38.733(.04)
30323 -001	Fandora	323	49.25	125.68	18.856(.07)	15.526(.04)	38.290(.04)
*30355 -001	Cream Lake	355	49.49	125.54	19.171(.04)	15.585(.04)	38.796(.07)
Average for Cluster 4 (n=3)					[19.002(.05)]	[15.617(.05)]	[38.702(.08)]
Standard deviation = S					0.172	0.031	0.133
Standard error mean = $Sn^{-1/2}$					0.099	0.018	0.065

* Asterisk denotes analysis used in calculation of averages.

study and lists the chief sources of information for each. Locations of the deposits are shown on Figure 1.

ANALYTICAL TECHNIQUES

Lead in galena from the samples was dissolved using HCl. Purified lead was obtained using anion columns and anodic electro-deposition. Samples were analysed using single-filament silica gel techniques on a 90-degree, 12-inch, solid source mass spectrometer. In-run precision, reported in the tables as per cent standard deviation within the brackets following mean isotopic ratios, is generally better than 0.1 per cent at one standard deviation. Multiple analyses of Broken Hill No. 1 standard shows that the reproducibility of sample analyses is about 0.1 per cent at one standard deviation. All data in the tables have been normalized to the Broken Hill No. 1 standard; normalizing procedures assumed the following composition for this standard: $^{207}Pb/^{204}Pb = 15.389$, $^{206}Pb/^{204}Pb = 16.003$, $^{208}Pb/^{204}Pb = 35.657$. All analyses were done in the Geology-Geophysics Laboratory, the University of British Columbia.

DATA

Galena-lead isotope data from Table 1 fall into four distinct clusters on the Pb-Pb plots of Figures 2 and 3. Each cluster corresponds to a deposit type and host rock group. Vein deposits are consistently more enriched in ^{206}Pb than are volcanogenic and related deposits. Sicker-hosted deposits are generally more enriched in ^{207}Pb than the Karmutsen and Bonanza-hosted deposits. The clusters, numbered 1 to 4 (Figures 2 and 3), are described in more detail below.

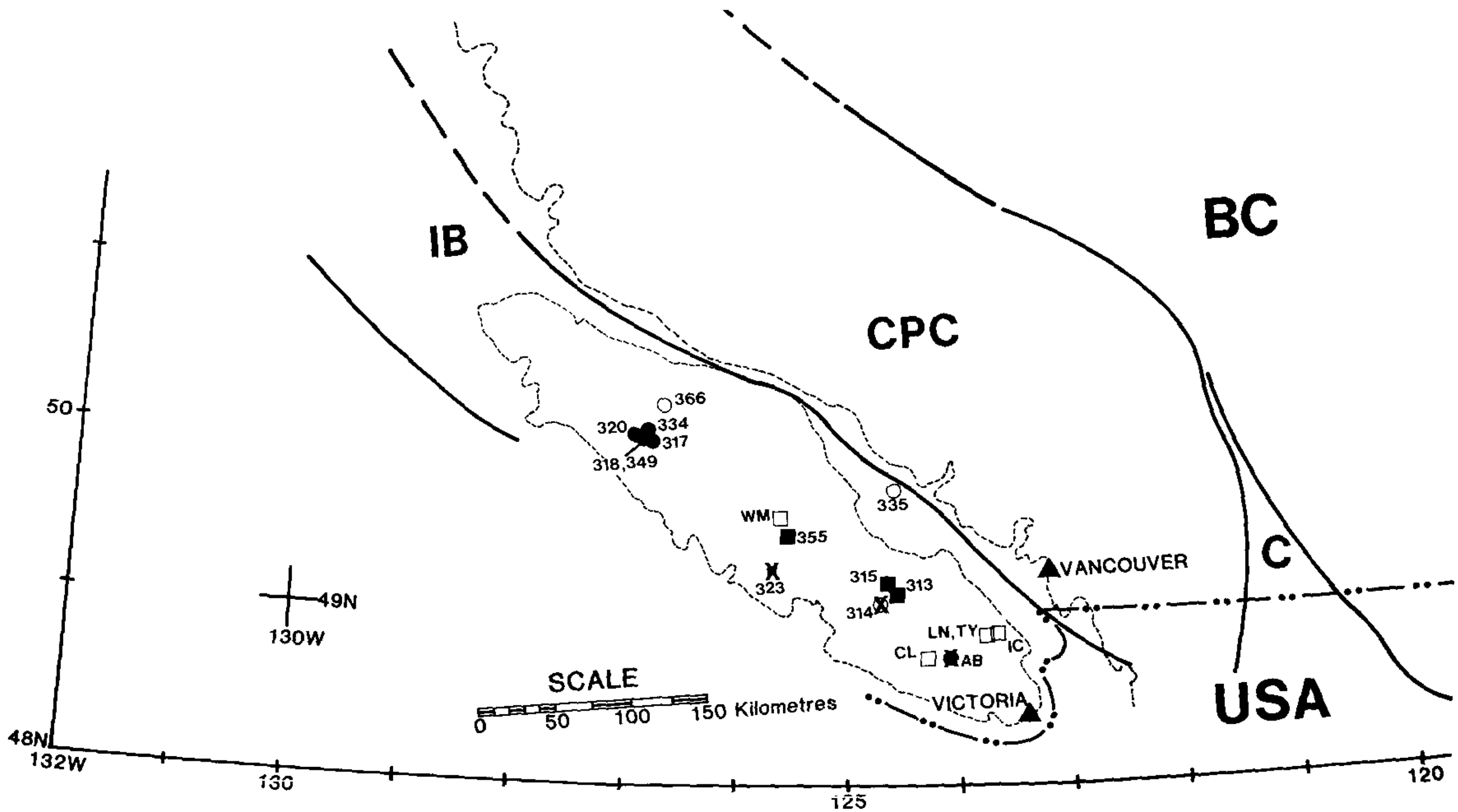

Figure 1. Location of galena-lead isotope analyses (Table 1) in Insular Belt, Canadian Cordillera; symbols are described on Figure 2.

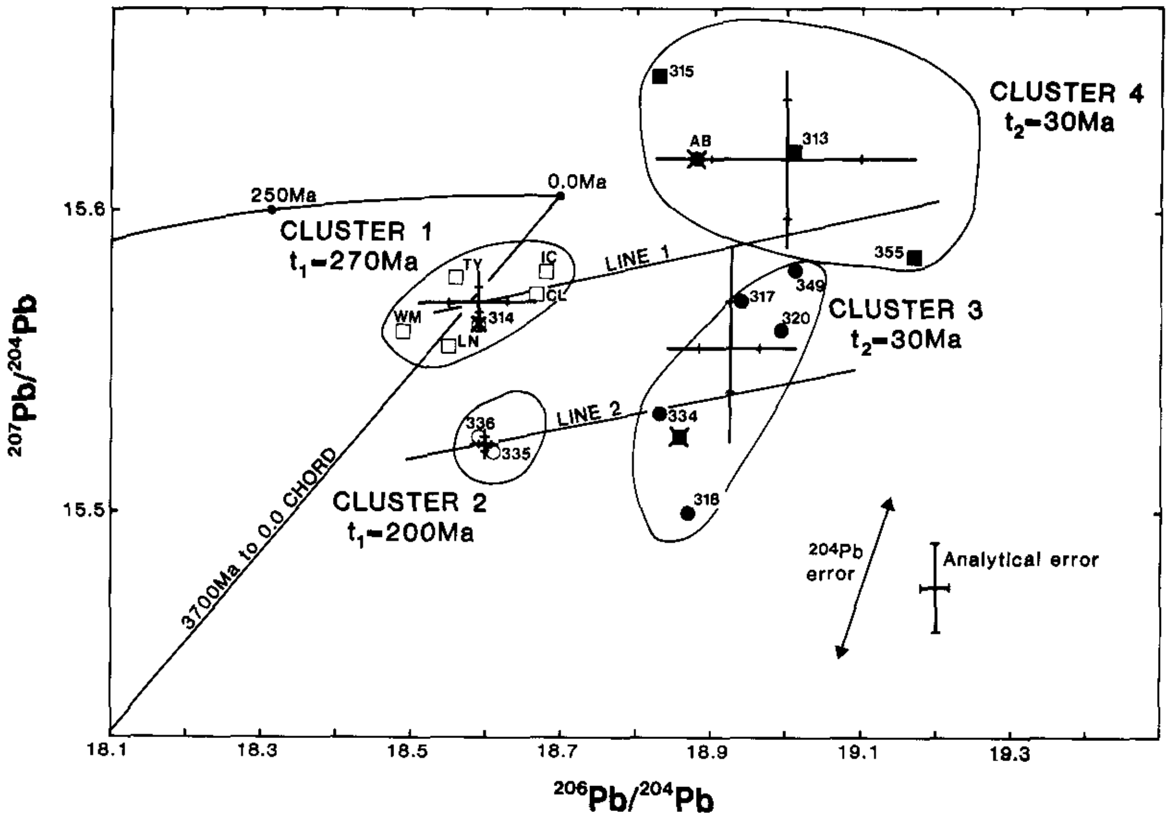

Figure 2. Galena-lead plot of $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ (Table 1). Open symbols are used for veins; circles denote deposits related to Karmutsen or Bonanza Group rocks; square symbols are for deposits related to Sicker Group rocks. Unreasonable analyses are crossed and are not used in our interpretation. Bars mark standard error of the mean and lines extends to standard deviation. Lines 1 and 2 represent the evolution of lead from t_1 to t_2 for varying values of μ; t_2 for Cluster 4 is not known with certainty (see text). The average growth curve shown is Stacey and Kramers (1975) curve for average crustal lead growth.

CLUSTER 1: SICKER GROUP VOLCANOGENIC AND RELATED DEPOSITS

The Sicker Group is made up of dominantly andesitic volcanic rocks and interbedded sedimentary and limestone units of Carboniferous-Permian age (Northcote, et al., 1972). On the basis of paleontological evidence (Muller and Carson, 1969), an age of 270 Ma has been assigned in this study to the deposits which make up this cluster.

Several volcanogenic massive sulphide deposits (and related showings) are contained in the Sicker Group, the best known being Western Mines (Figure 1). Lead isotope data from these deposits form a tight cluster in the Pb-Pb plots (Cluster 1, Figures 2 and 3) centred below the Stacey and Kramers (1975) curve for average crustal lead growth, but within the field of 'ocean volcanics' described by Doe and Zartman (1979). The compositions are too enriched in ^{206}Pb and too depleted in ^{207}Pb to plot on any 270-Ma isochron of the Stacey and Kramers (1975), Cumming and Richards (1975), or Doe and Zartman (1979) lead evolution models.

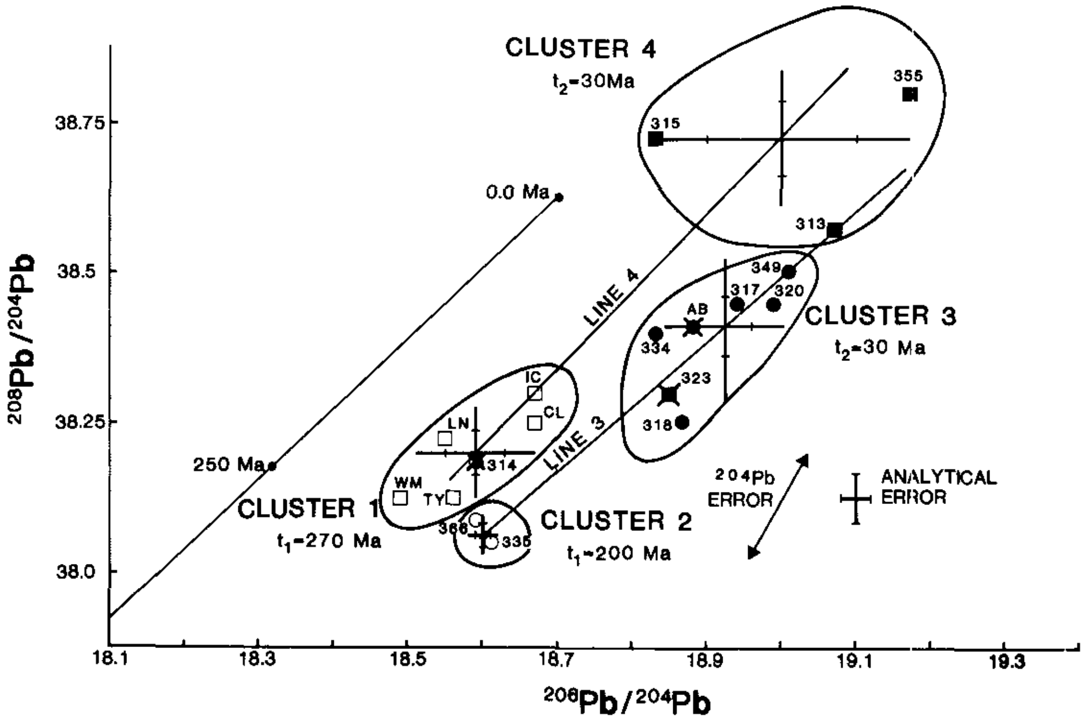

Figure 3. Galena-lead plot of $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ (Table 1); for symbol description see Figure 2. Lines 3 and 4 represent the evolution of lead from t_1 to t_2 for varying values of ω if K is 3.3 and 3.9 respectively (Table 2).

The Iron Clad deposit (Appendix) has not been classified previously as volcanogenic. We note that the composition of the lead is the same as other volcanogenic deposits in the Sicker Group. Consequently, we believe this deposit to be cogenetic with volcanogenic deposits within the Sicker Group.

CLUSTER 2: KARMUTSEN AND BONANZA GROUP VOLCANOGENIC AND RELATED DEPOSITS

Karmutsen Group volcanic rocks form a thick sequence of Triassic (circa 200 Ma) tholeiitic pillow basalts, flows, and breccias, which are similar in chemistry to those of mid-ocean ridges (Monger, et al., 1972). Muller (1971) and Souther (1977) suggested that they are volcanogenic arc rocks which formed close to a trench. They overlie the Sicker Group island arc assemblages and lack gabbro, chert, and ultramafic rocks which usually are associated with ocean basalts. In other words, they probably represent volcanic rocks generated above a Benioff zone during early stages of subduction.

Bonanza Group volcanic rocks are flows and pyroclastic layers ranging in composition from basalt to rhyolite. They overlie the Karmutsen Group and are dated as Middle Jurassic (circa 160 Ma) on the basis of radiometric ages from coeval granitic plutons (Muller and Carson, 1969).

Two deposits define Cluster 2; both are enclosed by Karmutsen volcanic rocks; consequently, an age of 200 Ma was assigned to both deposits for our purposes in interpreting lead isotopic data. Cluster 2 plots below the growth curve of Stacey and Kramers (1975) for average crustal lead (Figure 2) and is more depleted in ^{207}Pb than Cluster 1. If the age difference between Clusters 1 and 2 is taken into account, the difference in isotopic composition would be more pronounced, since Cluster 2 would have been even less radiogenic at 270 Ma.

The two deposits which define this cluster are not demonstrably volcanogenic and the term paramagmatic (White, et al., 1971) may be more suitable. Paramagmatic is the name given to epigenetic deposits which can be shown to be an integral part of a magmatic event. The lead isotopic composition of such a deposit probably reflects the composition of lead in the magma at its time of formation. We think that the relatively non-radiogenic Pb-isotope character of Cluster 2 reflects the isotopic characteristics of the enclosing Karmutsen volcanic rocks. The Starlight deposit (Table 1, Appendix) might belong to this cluster, but no mention is made in the literature of its host rock group, although the lead-isotopic composition plots within an area underlain by the Karmusten Group on regional geological maps (Muller, 1963). We exclude this deposit in our calculations but inclusion of this datum would make little difference to the mean position of Cluster 2.

CLUSTER 3: TERTIARY VEINS IN KARMUTSEN OR BONANZA GROUP VOLCANIC ROCKS

Bonanza and Karmutsen Group volcanic rocks are host to several quartz-gold veins from which, galena-lead isotope data were obtained. These veins vary in width. They are predominantly of quartz with minor carbonate and generally contain pyrite, sphalerite, chalcopyrite, galena, arsenopyrite, and gold. Spatially they are closely related to Tertiary quartz diorite stocks (Northcote and Muller, 1972). Three of the veins are within the Eocene Zeballos pluton (Appendix). Consequently, an age of 30 Ma was assigned to this cluster (Bancroft, 1940; Stevenson, 1950; Wanless, et al., 1967).

Galena from the veins which make up Cluster 3 has a uniform lead composition, the average of which is depleted in ^{207}Pb relative to Cluster 1, but is enriched in ^{206}Pb, ^{207}Pb, and ^{208}Pb relative to Cluster 2. The data plot beneath the Stacey and Kramers (1975) curve for average crustal lead and the average has a future model age.

Alpha and Beta deposit (Table 1, Appendix) belongs with Cluster 3 on geological evidence, but was excluded from calculations because of a highly anomalous $^{207}Pb/^{204}Pb$ value (Figure 2). It plots with Cluster 3 on Figure 3 but with Cluster 4 on Figure 2. Its high value in ^{207}Pb possibly results from analytical error which is greater for ^{207}Pb than for ^{206}Pb and ^{208}Pb.

CLUSTER 4: TERTIARY VEINS IN SICKER GROUP ROCKS

Quartz-gold veins in Sicker Group rocks that form Cluster 4 on Figures 2 and 3 have the same general appearance and mineralogy as those of Cluster 3 (Muller and Carson, 1969).

Although Cluster 4 forms a distinctly different group relative to Cluster 3, there are only three data points which are quite widely scattered on the Pb-Pb plots. The average composition of the cluster is more radiogenic than the average for any of the other clusters. Although the age of those veins is not known with certainty an age of 30 Ma was assigned on the basis of the similarity in ^{206}Pb content with Cluster 3, and the assumption that they are related to the same phase of intrusive activity. Victoria showing (Table 1, Appendix) may be an older deposit related to the Jurassic Island Intrusions. The age t_2 of Cluster 4, however, is not crucial to the hypothesis proposed in this study. Fandora deposit (Table 1, Appendix) belongs to this group on geological grounds, but was not included in the discussion because of its anomalously low radiogenic lead contents; the sample is to be re-analysed.

LEAD ISOTOPE MODELS

Distribution of the four clusters on Figure 2 gives the appearance of two parallel trends. One is from Sicker-hosted volcanogenic to vein deposits (line 1, Clusters 1 and 4), the other from Karmutsen and Bonanza-hosted volcanogenic and related deposits to vein deposits (line 2, Clusters 2 and 3).

Four possible explanations for these groupings are:

(1) vein lead is unrelated to the volcanogenic lead,
(2) vein lead lies on an isochron with the volcanogenic lead,
(3) vein lead lies on a growth curve with volcanogenic lead, and
(4) vein lead lies close to a growth curve with volcanogenic lead but is preferentially enriched in radiogenic lead.

The first hypothesis appears unlikely on the general grounds that the relative plot positions of the two 'volcanic' clusters are identical with the relative plot positions of the two younger vein clusters. One 'volcanic' and one vein cluster have evolved in environments with low uranium/lead ratios (Clusters 2 and 3) compared with the other volcanic-vein pair of clusters. This seems an unreasonable coincidence. It is more likely that volcanic-vein pairs of clusters are somehow genetically related. The relationship was tested by calculating the slopes of the lines that pass through Clusters 1 and 2 (Figure 2, Lines 1 and 2), with pairs of ages 270 and 30 Ma, and 200 and 30 Ma respectively, using Equation 3 (Table 2). In both cases the lines pass through their respective vein clusters but not through the averages of the vein clusters (Figure 2). This result shows that the parallel trend is significant and therefore hypothesis one can be eliminated.

Equation 1: $$\left[\frac{^{206}Pb}{^{204}Pb}\right]_{t_2} = \left[\frac{^{206}Pb}{^{204}Pb}\right]_{t_1} + \mu(e^{\lambda_1 t_1} - e^{\lambda_1 t_2})$$

Equation 2: $$\left[\frac{^{207}Pb}{^{204}Pb}\right]_{t_2} \quad \left[\frac{^{207}Pb}{^{204}Pb}\right]_{t_1} + \frac{\mu}{137.88}(e^{\lambda_2 t_1} - e^{\lambda_2 y_2})$$

Equation 3: $$M_{207-206} = \frac{1}{137.88}\left[\frac{\left[^{207}Pb/^{204}Pb\right]_{t_2} - \left[^{207}Pb/^{204}Pb\right]_{t_1}}{\left[^{206}Pb/^{204}Pb\right]_{t_2} - \left[^{206}Pb/^{204}Pb\right]_{t_1}}\right]$$

$$= \frac{e^{\lambda_2 t_1} - e^{\lambda_2 t_2}}{e^{\lambda_1 t_1} - e^{\lambda_1 t_2}}$$

Equation 4: $$M_{208-206} = k\,\frac{(e^{\lambda_3 t_1} - e^{\lambda_3 t_2})}{(e^{\lambda_1 t_1} - e^{\lambda_1 t_2})}$$

$\mu = {}^{238}U/^{204}Pb$ $\qquad k = {}^{232}Th/^{238}U$ $\qquad w = k\mu$

$\lambda_1 = 0.155125 \times 10^{-9}$ (Jaffey et al., 1971)

$\lambda_2 = 0.98485 \times 10^{-9}$ (Jaffey et al., 1971)

$\lambda_3 = 0.049475 \times 10^{-9}$ (LeRoux and Glendenin, 1963)

$M_{207-206}$ and $M_{208-206}$ are slopes of isochrons on the Pb-Pb plots.

TABLE 2. EQUATIONS USED IN LEAD ISOTOPE MODEL CALCULATIONS

Hypothesis two can be dismissed on geological grounds since there is clearly a large age difference between the syngenetic volcanogenic deposits and epigenetic veins. The distinction between vein and volcanogenic lead in $^{206}Pb/^{204}Pb$ ratio is marked and provides a method for distinguishing epigenetic versus syngenetic deposits in the Insular Belt. All the epigenetic deposits have $^{206}Pb/^{204}Pb$ ratios greater than 18.8, and the syngenetic deposits have ratios less than 18.7. Iron Clad is an example of one showing which was thought to be epigenetic but which is likely syngenetic on the basis of its isotopic composition.

Hypothesis three can be tested by calculating the apparent $^{238}U/^{204}Pb$ (μ) value which would be required to produce the vein lead compositions from the volcanogenic lead compositions in the time intervals 270 to 30 Ma and 200 to 30 Ma, using equations 1 and 2 (Table 2). This method is based on the assumption that the volcanogenic lead is representative of the composition of the lead in the volcanic host rocks at their time of formation (t_1) to the time of vein mineralization (t_2). The amount of change in the ratios over any time interval depends on the value of $^{238}U/^{204}Pb$ (μ) and $^{232}Th/^{204}Pb$ (ω). Apparent μ values were calculated and found to be high relative to expected values (Faure, 1977; Doe and Zartman, 1979). Thus, the veins are more enriched in radiogenic lead than would be expected if they fell on growth curves with the volcanogenic lead. This causes us to reject hypothesis three. The apparent high μ values noted above, however, might be because radiogenic lead is more easily removed from source rocks than is common lead (because of its unstable position in mineral lattices). An ore-forming fluid would therefore be able to scavenge more radiogenic lead than common lead and so would give rise to a lead deposit with an artifically high apparent μ. This process of radiogenic enrichment has been observed at Beaverdell (Watson, et al., in preparation) and in the Mississippi Valley (Heyl, et al., 1974) and supports hypothesis four.

Strong support for hypothesis four comes from the observations that lines 3 and 4 (Figure 3), which pass through the centres of both pairs of clusters, have slopes which give geologically reasonable $^{232}Th/^{238}U$ (k) values. k values were calculated using equation 4 (Table 2) and found to be 3.9 for line 3 and 3.3 for line 4. These values are close to those listed for volcanic rocks by Faure (1977).

SOURCE OF GOLD

The source of gold in vein deposits is controversial. Boyle (1979) summarized three possibilities:

(1) gold comes from an abyssal source such as the mantle,
(2) gold comes from a plutonic source, and
(3) gold comes from the host rocks by processes such as metamorphic secretion or hydrothermal extraction and deposition.

Each of these hypotheses is discussed with respect to the lead isotope data, based on the assumption that the origin of the lead is the same as that of the associated gold.

Lead from an abyssal source would have a depleted isotopic composition due to the absence of uranium and thorium-rich minerals in the mantle (Faure, 1977). Galena in the Bonanza and Karmutsen-hosted veins (Cluster 3, Figures 2 and 3) is notably depleted in ^{207}Pb and must therefore have a source which is less radiogenic than the Sicker volcanic rocks (Cluster 1, Figures 2 and 3). If this source was the mantle, then all the quartz-gold veins of the same age and within a limited geographical area, would have a uniform lead composition irrespective of host rock group. Recognition of two groups of veins with different isotopic compositions, corresponding to different host rock groups, tends to negate this hypothesis. The unradiogenic nature of the Karmutsen and Bonanza volcanic rocks (Cluster 2, Figures 2 and 3) provides an adequate source for the lead without appealing to an abyssal source.

Cluster 3 (Figures 2 and 3) deposits (Privateer, White Star, and Lone Star) are all spatially related to the Zeballos pluton, the latter two occur within the pluton itself (Appendix). If the source of the metals in each vein was plutonic, then one might expect to see either a uniform composition of lead in the veins, unrelated to host rock, or variations in the vein lead compositions corresponding to different plutons. The close correlation between vein composition and host rock group is too persuasive to allow for all of the metal to have been introduced from plutons.

Close spatial association of the quartz-gold veins to Tertiary quartz diorite intrusions suggests that the plutons play a role in the mineralizing process. We suggest that the plutons provided a heat source that circulated hydrothermal fluids through the host rocks; these fluids extracted radiogenic lead and gold from the volcanic terrane and precipitated these metals in quartz veins. This model is in accord with Boyle's third proposition, namely that the host rocks provided the metals which were mobilized and concentrated by igneous, hydrothermal activity. Consequently, the isotopic composition of the lead in the veins is a reflection of its host rock.

CONCLUSIONS

Lead isotope data from volcanogenic and quartz-gold vein deposits in the Insular Belt suggest that the gold in veins was derived from their host rocks. Extraction, concentration, and deposition were probably by hydrothermal fluids mobilized in geothermal cells generated adjacent to Tertiary plutonic centres.

Lead isotopic compositions for quartz-gold veins of the southern Insular Belt are depleted in ^{207}Pb relative to silver-bearing veins in the Yukon Tertiary (Godwin, et al., in press), reflecting the more primitive volcanic source terrane of the Insular Belt. The uniformity of the vein lead compositions of Cluster 3 contrasts with the linear patterns of data for vein deposits elsewhere in the Cordillera (Doe and Zartman, 1979; Godwin, et al., in press). There is also evidence that radiogenic enrichment of lead in veins, noted in the Insular Belt quartz-gold veins, occurred in other silver-gold veins, for example, in the Beaverdell camp in south-central British Columbia (Watson, et al., in preparation).

From a practical point of view, isotopic analyses of galena appears useful in distinguishing young epigenetic vein deposits from older volcanogenic deposits (perhaps with related veins). This distinction will have an effect on the approach to detailed exploration within the Insular Belt.

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APPENDIX

Western Mines:	Lat. 49•57°; Long. 125•59°; 92F/12E
Sample Nos.:	G79WM-001, 002, and 003.
Description:	It is a kuroko-type massive sulphide deposit. Lenses, veins, and mosses of pyrite, chalcopyrite, sphalerite, and galena occur in Sicker Group rhyolitic volcanic rocks.
Metals Recovered:	Copper, zinc, lead, gold, silver, cadmium, and barite.
Reference:	MDI No. 092/071.

Lenora:	Lat. 48•87°; Long. 123•78°; 92B/13W
Sample Nos.:	G79LN-001 and 002.
Description:	This is described as a 'replacement' ore, but is probably a volcanogenic massive sulphide in Sicker Group folded tuffs. Two ore types occur: barite ore is a fine-grained mixture of pyrite, chalcopyrite, sphalerite, and galena in a barite, calcite, and quartz gangue; and quartz ore is mainly quartz and chalcopyrite.
Metals Recovered:	Zinc, copper, silver, barite, and lead.
Reference:	MDI No. 092F/001.

Tyee:	Lat. 48•87°; Long. 123•78°; 92B/13W
Sample No.:	G79TY-001.
Description:	This is described as a 'replacement' ore, but is probably a volcanogenic massive sulphide in Sicker Group folded tuffs. Two ore types occur: barite ore is a fine-grained mixture of pyrite, chalcopyrite, sphalerite, and galena in a barite, calcite, and quartz gangue; and quartz ore is mainly quartz and chalcopyrite.

Cowichan Lake:	*Lat. 48•7°; Long. 124•78°; 92C/16W*
Samples Nos.:	G79CL-001, 002, and 003.
Description:	Permo-Carboniferous Buttle Lake Formation limestone (Sicker Group) is underlain by Sicker Group cherts, tuffs, and breccias and overlain by Karmutsen Formation basalt and diabase.
References:	B.C. Ministry of Energy, Mines & Pet. Res., Bull. 40, p. 46; Bull. 37, p. 16.

Iron Clad:	Lat. 48•85°; Long. 123•68°; 92B/13E
Sample No.:	G79IC-001.
Description:	Sphalerite, pyrrhotite, and chalcopyrite mineralization occurs in a shear zone of quartz-sericite schist of Sicker Group.
Metals Recovered:	Zinc and copper.
References:	Minister of Mines, B.C., Ann. Rept. 1904, p. 253; Assessment Report 19.

Bon:	Lat. 50•27°; Long. 126•67°; 92L/7E
Sample No.:	30366-001.
Description:	The Bon mineral occurrences are in predominantly volcanic rocks of the Karmutsen Formation in the type area (GEM, 1970, pp. 274-278). Principal showings are replacements of certain volcanic layers by skarn with either magnetic or pyrrhotite. One conflicting report suggests that Bon is in Bonanza Group rocks (Assessment Report 1821).
Metals Recovered:	Iron and copper.
References:	B.C. Ministry of Energy, Mines & Pet. Res., GEM, 1970, pp. 274-278; Assessment Report 1821.

Nutcracker: Lat. 49•75°; Long. 124•59°; 92F/10E

Sample Nos.: 30335-001.
Description: Brown porphyrite (Karmutsen ?) is traversed by several fissure zones 3 to 4 feet wide, rarely completely filled with quartz. Usually narrow veinlets occupy the zones. A contact with the Marble Bay Limestone occurs to the southeast. Galena and chalcopyrite occur in the quartz.
References: MDI No. 092/359; Assessment Report 6414.

Starlight: Lat. 49•06°; Long. 125•54°; 92F/3E

Sample Nos.: 30314-001.
Description: Fine-grained free gold is associated with galena that is finely disseminated through extensively altered diabase.
Metal Recovered: Gold.
References: MDI No. 092/216; Geol. Surv., Canada, Map 49-1963.

Cream Lake: Lat. 49•49°; Long. 125•54°; 92F/5E

Sample No.: 30355-001.
Description: Veins of quartz with lesser siderite and calcite contain values in silver, gold, zinc, and copper. They are underlain by volcanic rocks and lesser sedimentary rocks of Permian age and overlain by Karmutsen volcanic rocks. A distinct band of Permian limestone occurs between the two. The Western Mines' orebodies lie to the north within this belt.
Metals Recovered: Gold, silver, copper, and zinc.
Reference: Assessment Report 1884.

Golden Eagle: Lat. 49•11°; Long. 124•59°; 92F/2E

Sample No.: 30313-001.
Description: Gold occurs in a vein of ribbon quartz and pyrite with other minor sulphides in a small intrusion of feldspar porphyry.
Metal Recovered: Gold.
References: MDI No. 092F/080; Geol. Surv., Canada, Paper 68-50.

Victoria: Lat. 49•18°; Long. 124•66°; 92F/2E

Sample No.: 30315-001.
Description: Gold and pyrite are associated with quartz veins in sheared sections of andesitic flows and tuffs. The rock groups observed were placed tentatively in the Sicker Group, though government geologists left them in the Island series. The deposit is adjacent to a stock related to the Coast Range Batholith (that is, this vein is probably an older vein than the others).
Metals Recovered: Gold, silver, and copper.
References: MDI No. 092F/079; Geol. Surv., Canada, Paper 68-50; Assessment Report 4914.

Fandora: Lat. 49•25°; Long. 125•68°; 92F/5E

Sample No.: 30323-001.
Description: Gold and silver-bearing veins of quartz with some carbonate, finely crystalline pyrite, and rarely lerite cut altered volcanic rocks near andesitic dykes in one working close to a small mass of intrusive quartz diorite.
Metals Recovered: Gold, silver, copper, lead, and zinc.
References: MDI No. 092F/040; Geol. Surv., Canada, Paper 68-50.

White Star: Lat. 50•30°; Long. 126•81°; 92L/2W

Sample No.: 30318-001.
Description: Quartz diorite of Eocene Zeballos pluton is cut by feldspar porphyry dykes and subsequently jointed in three directions. Quartz veins with pyrite, galena, arsenopyrite, sphalerite, and gold occur in gangue and breccia zones along which fault movement has taken place. The sulphides are usually concentrated in bands along the walls of the veins.
Metals Recovered: Gold, silver, lead, and zinc.
References: MDI No. 092L/010; Geol. Surv., Canada, Paper 40-12.

Lone Star-Rey-Oro: Lat. 50•02°; Long. 126•79°; 92L/2W

Sample No.: 30317-001.
Description: Quartz diorite of Zeballos pluton is cut by aplite and andesitic and feldspar porphyry. Many quartz veins with galena, arsenopyrite, gold, chalcopyrite, and sphalerite occur in shears in jointed quartz diorite and the dykes.
Metals Recovered: Gold, silver, zinc, lead, and copper.
References: MDI No. 092L/015; MINDEP 05841.

Peerless: Lat. 50•04°; Long. 126•84°; 92L/2W
Sample No.: 30320-001.
Description: A quartz vein 5 centimetres wide follows a contact between a feldspar porphyry dyke and feldspathized andesite of Lower Jurassic Bonanza Group. Quartz contains abundant calcite and small amounts of sphalerite and chalcopyrite.
Metals Recovered: Gold, zinc, and copper.
References: MDI No. 092L/025; MINDEP 05851.

Privateer: Lat. 50•03°; Long. 126•81°; 92L/2W

Sample No.: 30349-001.
Description: Quartz veins with pyrite, sphalerite, galena, arsenopyrite, pyrrhotite, and native gold cut massive Bonanza Group volcanic rocks, lime silicates, and small bodies of Jurassic intrusive quartz diorite.
Metals Recovered: Silver, gold, copper, and lead.
References: MDI No. 092L/008; Geol. Surv., Canada, Paper 1940-12.

Alpha, Beta: Lat. 48•73°; Long. 124•09°; 92C/9E

Sample No.: G79AB-001.
Description: Franklin Creek (Karmutsen Formation) andesite and lenses of Quatsino limestone are cut by dykes of granodiorite, granite porphyry, and diorite porphyry. Limestone, andesite, and granodiorite are partly altered to garnet-epidote-pyroxene skarn with chalcopyrite, magnetite, and pyrite locally.
References: MDI No. 092C/039; B.C. Ministry of Energy, Mines & Pet. Res., GEM, 1970, p. 291; 1971, p. 226.

Lucky Strike: Lat. 50•06°; Long. 126•84°; 92L/2W

Sample No.: 30334-001.
Description: The Vancouver-G 1 shear, which follows a feldspar porphyry dyke in diorite and granodiorite breccia, contains lenses of quartz 5 to 7.5 centimetres wide with pyrite and free gold.
Metals Recovered: MDI No. 092L/030; MINDEP 05856; Geol. Surv., Canada, Mem. 272, p. 59.