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INTERPRETATION OF GALENA LEAD ISOTOPE SIGNATURES OF MINERAL DEPOSITS OF THE PELLY - CASSIAR PLATFORM

1. Introduction

The Pelly - Cassiar Platform (PCP) is a 600 kilometre long, curvilinear segment of the western North American miogeocline outboard of the craton and separated from it by the Selwyn Basin and Kechika Trough. It has been variously interpreted as a segment of the Peace River Arch that was transported northwesterly over 600 kilometres by Cretaceous to Eocene dextral transcurrent faulting (Gabrielse, 1985), and as a horst formed during Late Proterozoic or Early Cambrian rifting which has undergone about 450 kilometres of dextral transport (Roddick, 1964, Tempelman - Kluit, [illegible], Mortenson, 1981).

From Lower Cambrian to Upper Devonian time the PCP was the site of accumulation of thick shallow water carbonate and siliciclastic shelf sediments and lesser thin bedded calcareous siltstones and volcanic rocks, while thick basinal shales and cherts were deposited in the Selwyn basin. The Paleozoic basinal succession overlapped onto the PCP beginning in latest Devonian time, as extensive rifting, block faulting, and subsidence occurred along the western margin of North America. Devono - Mississipian basinal successions [illegible] turbidites comprise the Earn Group, which consists of [illegible] debris derived from relatively uplifted platformal blocks (Gordey *et al.*, 1986).

Galena lead isotope data for mineral deposits occurring within the PCP and in overlying allochthonous oceanic rocks are presented in Table 1. These data are drawn from a variety of syngenetic and epigenetic deposit types in different lithotectonic settings, and therefore juxtapose diverse source regions and mineralization pathways. Recent exploration interest has focussed on epigenetic carbonate - hosted skarn and manto deposits (Ketza River, Tintina Silver, Midway, Silver Hart). Gold - quartz veins in the Sylvester Allochthon with affinities to Archaean gold deposits constitute another significant exploration target, and support two mines in the Cassiar area.

2. Lead Source Terranes

Both the Paleozoic successions of the Selwyn Basin and Kechika Trough, and siliciclastic shelf and turbidite sediments of the PCP represent recycled Precambrian material derived ultimately from the North American craton. Both basinal and platformal facies comprise highly radiogenic upper crustal material which has been relatively isolated from significant mantle input since Early Hadrinian time. Sediment hosted base metal (SHBM) deposits in the Selwyn Basin, Kechika Trough, and in the southern Cordillera were used by Godwin and Sinclair (1982) to define lead growth curves applicable to galena lead derived from North American upper crustal material. Age of these deposits is well constrained by the age of their host sediments. Evolution of lead in this source terrane by addition of radiogenic lead over time up until the mineralizing event can therefore be used to support model ages for deposits in which lead is predominantly of this type. Since the isotopic characteristics of lead within this terrane are approximately known for a given age, the relative contribution of lead from this source can be assessed for dated deposits in which the source of lead is in question. This can provide information on the nature of the mineralizing system and fluid pathways.

It is important to note, however, that the "shale curves" are average growth curves for the Canadian Cordillera. Isotopic inhomogeneities within the source terrane may give rise to significant departures from shale curve model ages. Further, it is important to recognize to what extent specific tectonic provinces such as the PCP may have isotopic characteristics deviation from shale curve averages.

In the Pelly Mountains, Earn Group strata contain alkalic felsic volcanics which host several showings of volcanogenic massive sulphide (VMS) affinity (Mortenson, 1979, 1981). The tectonic setting of these showings is an unusual combination of a rifted marginal basin with felic volcanics in a previously miogeoclinal terrane. Lead in this setting may be derived in part from surrounding euxinic basin strata, or from underlying shelf sediments, and to this extent should fit a shale curve model. However, lead derived from the volcanics would fit the shale curve only if they were melts formed from North American upper crustal material; otherwise some lower crustal or mantle input is likely.

Allochthonous terranes overlying the PCP include the Sylvester and Anvil - Campbell Allochthons, of Upper Paleozoic to Triassic age. These consist mainly of oceanic sediments and volcanics, and widespread ultramafites. The lowermost division of the Sylvester Allochthon may be transitional to north American marginal basin facies (Earn Group), and contains imbricates of continentally derived material cut by basaltic feeder systems. The Sylvester also contains a substantial intermediate rift or arc volcanic component and intrusive equivalents (Nelson et al., 1988). Lead derived from these packages may be complex and heterogeneous, but probably contains a significant mantle component.

A final complexity in the source terrane model for the PCP is introduced by Mezozoic - Cenozoic intrusions, which are associated with a variety of epigenetic deposits. Depending on type of intrusion, derivation of melts, and subsequent contamination, these may contribute lead with isotopic characteristics significantly different from country rocks hosting the deposits.

At least three separate Mezozoic - Cenozoic intrusive events have occurred within or adjacent to the PCP. The oldest is represented by the Cassiar batholith, a voluminous 110 - 95 Ma plutonic welt suturing North American rocks and outboard suspect terranes (Cache Creek, Klondike - Oblique, Stikinia, Quesnellia).

Younger, volumetrically smaller sets of intrusions are widespread throughout the PCP, and are associated with epigenetic deposits to a far greater degree than the Cassiar batholith. Late Cretaceous (70 - 75 Ma) intrusions include the Troutline, Kuhn, and Windy stocks in the Cassiar area, and a buried intrusion southeast of the Midway deposit in the Rancheria district (Panteleyev, 1985, Bradford and Godwin, 1988). These intrusions host Mo - W mineralization and are associated with significant F anomalies and Sn bearing Ag-Pb-Zn showings.

The youngest major set of intrusions is of Eocene age (58 - 50 Ma), and includes the Mount Haskin - Mount Reed stocks, east of Cassiar, intrusions associated with the Butler Mountain (YP) Ag-Pb-Zn, Fiddler Sn, and Hot W prospects in the Rancheria district, and buried intrusions associated with Au-Ag mantos in the Ketza River camp Christopher, Dawson, Sinclair, Goodwin (references). These felsic intrusives are associated with F, Sn and W anomalies, and in some cases contain fluorite or topaz and may be considered A - type (anorogenic) granites (W.D. Sinclair, personal communication, 1986). An Initial Sr value of .7125 for the Butler Mountain stock is more typical of a lthophile element enriched upper crustal (S - type) melt (R.L. Armstrong, unpublished data), although Sr isotope characteristics of lower crust underlying the PCP are unknown

The younger intrusions were emplaced during Cordilleran - wide dextral transcurrent faulting which was accompanied by more localized extension and compression. In the Rancheria district, a north trending zone of extensional faulting contains intrusions of both Late Cretaceous and Eocene epidodes. The presence of felsic granites in district - scale zones of extension may represent an influx of lower crustally derived material, variably contaminated by upper crustal material during magmatic ascent (Collins et al., 1982, Whalen et al., 1987). Lead in associated deposits may reflect this variable lower crustal signature.

In summary, the character of lead in deposits in the PCP reflects considerable variabilty in source terranes. The distinctly upper crustal Paleozoic platform and basin successions may deviate from average Cordilleran growth curve models and may contain internal inhomogeneities, the alkalic felsic volcanics in the Pelly Mountains being a conspicuous example. Allochthonous terranes overlying the PCP contain oceanic volcanics, sediments, ultramafites, and intermediate rift or arc volcanics, and represent a heterogeneous source with a significant mantle component. Finally, post mid - Cretaceous intrusions may have introduced a lower crustal component with variable upper crustal contamination into widespread epigenetic deposits.

3. Interpretation of Lead Isotope Signatures

Lead isotope data from PCP deposits tabulated in Table 1 is plotted on Pb 207/Pb 204 versus Pb 206/Pb 204 (7/4-6/4) and Pb 208/Pb 204 versus Pb 206/Pb 204 (8/4-6/4) diagrams in Figures 1 and 2. Major deposit groups as listed in Table 2 are circled, and shale curves of Godwin and Sinclair (1982) are superimposed on both plots.

3.1. Syngenetic Deposits

The data show good separation of deposit types on both plots, with limited overlap of Cassiar Ag and Cassiar Au, and Cassiar Ag and Rancheria - Ketza groups on the 7/4-6/4 plot. Deposits interpreted as syngenetic in Paleozoic strata are distinct from epigenetic deposits of Cretaceous and younger age. This signature can be used to constrain models for deposits of uncertain origin. For example, the Howru showing consists of poorly stratabound disseminated galena in Siluro - Devonian siliciclastics (reference). Lead data demonstrably rules out an epigenetic replacement model for this showing, which must have a syndepositional or diagenetic origin.

Syngenetic deposits generally show poor correspondance with shale curve model ages. Earn Group VMS deposits in the Pelly

Mountains of Mississipian to Pennsylvanian age define an elongate group intersecting the growth curve at the Devono - Mississipian boundary. Elongation of data clusters with steep slopes is probably due to Pb 204 error or fractionation. The lead signature is Pb 206, 207, and 208 - poor relative to growth curve averages for lead of this age of mineralization. The Blue showing, an Earn Group SHBM deposit of probable Early Mississipian age, shows an even more marked shift to the left on both plots, plotting near the Ordovician - Silurian boundary. Thus Earn Group basinal deposits of the PCP appear to be depleted in radiogenic lead relative to the Cordilleran average, reflecting lower μ and ω values for their host succession.

SHBM deposits of Cambro - Ordovician age (Meister, Sir John A) appear to be erratically distributed. The Meister deposit, in Lower Cambrian Atan Group metapelites (reference), plots near the Cambro - Ordovician boundary on the 7/4-6/4 plot, and near the Ordovician - Silurian boundary on the 8/4-6/4 plot. The Sir John A showing in Cambro - Ordovician Kechika Group phyllite, plots near the Silurian - Devonian boundary on the 7/4-6/4 diagram and near the Devono - Mississipian boundary on the 8/4-6/4 plot. The two showings thus show enrichment in radiogenic lead relative to shale curve averages.

The apparent shift from relative enrichment in syngenetic deposits in platformal rocks to radiogenic lead depletion in deposits in later basinal successions may reflect differences in μ

and ω among the Selwyn Basin, PCP, and Earn Group. More analyses are needed to adequately document this heterogeneity. The data shown here exhibit poor correlation with shale curve model ages, with the deviations being suggestive of a higher μ and ω for the PCP relative to Cordilleran averages, and input of less radiogenic lead into deposits hosted in the Earn Group, perhaps derived from lower crustal or mantle sources.

3.2. Epigenetic Deposits

Epigenetic deposits of the Cassiar area are markedly less radiogenic than deposits from the Rancheria and Ketza River districts. Cassiar deposits include three groups: (1) gold - quartz veins in the Sylvester Allochthon (Erickson, Cusac); (2) Ag-Pb-Zn and W skarns and replacements in platformal carbonates, related to 72 Ma intrusions (D Zone, Weisman, Coast Ag, Ray 2, Contact); and (3) VMS deposit in the Sylvester Allochthon (Lang Creek).

Potassium - argon dates on sericite from quartz veins of Group 1 deposits cluster around 125 Ma (Sketchley et al., 1986). These veins may be related to deep fluid infiltration along faults, driven by anomalous geothermal gradients preceding emplacement of the Cassiar batholith. Lead isotope data shows poor correlation of K-Ar ages with shale curve model ages, which range from Permian to mid - Jurassic on both plots. In addition, the data falls well below the 8/4-6/4 growth curve, and somewhat below the 7/4-6/4 curve. This suggests input of lead from a low μ and ω source, probably the basalt - argillite - ultramafite host sequences. On the 7/4-6/4 plot, Erickson lead shows a moderate - slope linear trend (one analysis excepted) which is a possible mixing line (cf. Andrews et al., 1984). Moreover, on the 8/4-6/4 plot Pb 208 depletion relative to the shale curve lies in the direction of the Lang Creek VMS showing, generated in a thorium depleted environment of mantle origin. Lead signatures for these deposits are thus compatible with mixing of lead from a shale curve - type upper crustal terrane (the PCP underlying the Sylvester) with lead derived from the host strata, which contain a significant mantle component.

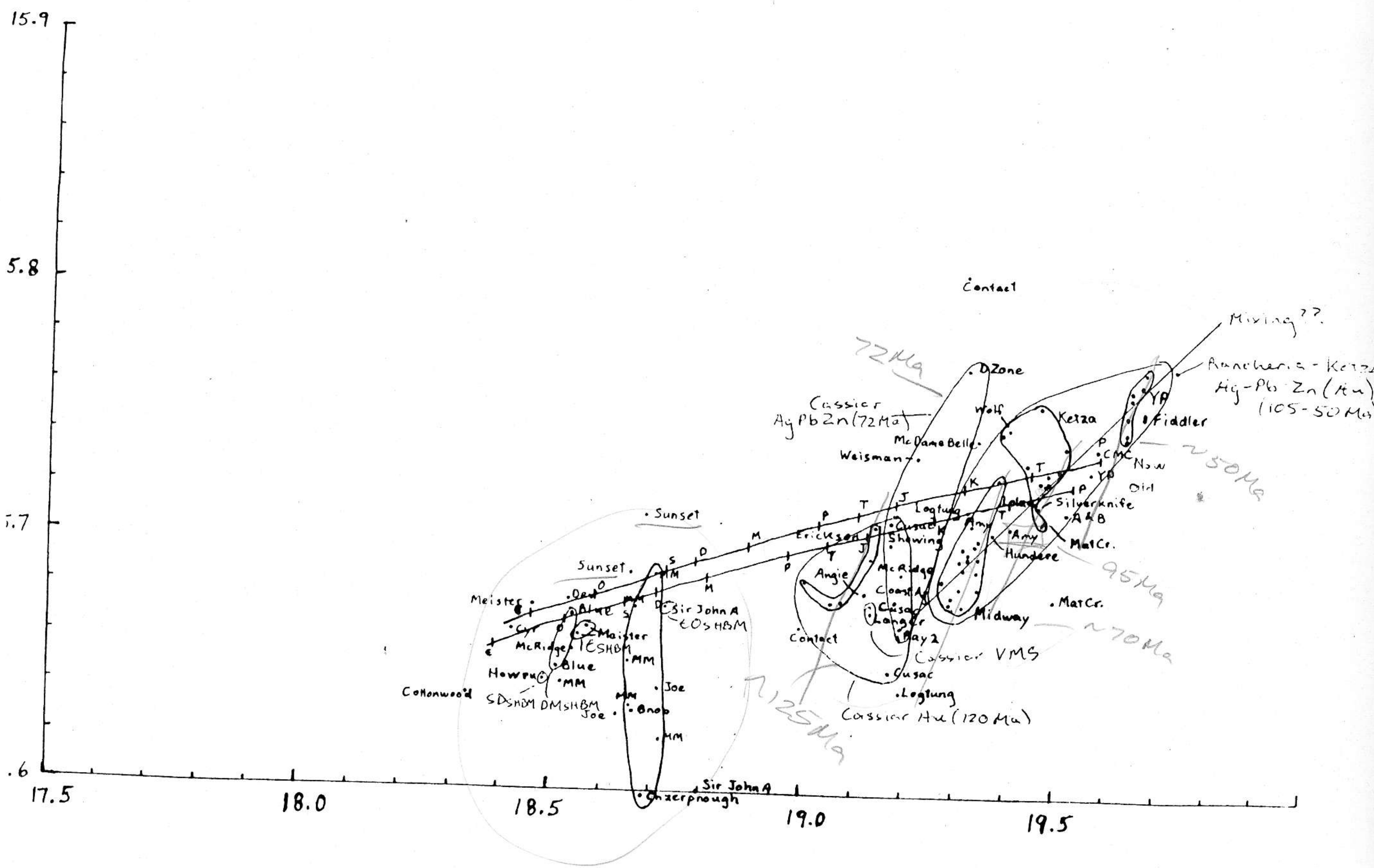
Group 2 Cassiar deposits fall into an elongate cluster parallel to Pb 204 error lines. The cluster intersects the shale curves at mid - Jurassic and mid - Cretaceous model ages on the 7/4-6/4 and 8/4-6/4 plots, respectively. These deposits thus show a slight depletion of radiogenic lead relative to shale curve averages. Enrichment of Pb 208 relative to group 1 deposits is not due to younger age of mineralization, since the enrichment occurs at a steeper slope than the growth curve. This probably reflects lack of input of low ω - lead from the Sylvester Allochthon. The slight difference from shale curve model ages may be a function of poor analyses, distinctiveness of PCP lead from shale curve average lead, or input of upper crustal lead from intrusions (Cooke and Godwin, 1984).

Lead isotope signatures from epigenetic deposits of the Rancheria and Ketza River districts are distinctly more radiogenic than Cassiar area deposits of similar age. The Rancheria - Ketza group includes deposits associated with late stage differentiates of the Cassiar batholith (Amy, ~95 Ma), deposits associated with Late Cretaceous intrusions (Midway, Silverknife?, ~ 70 Ma), and deposits associated with Eocene intrusions (Ketza River, ~58 Ma, and YP and Fiddler, ~ 50 - 55 Ma). The most radiogenic of these deposits give future model ages relative to the shale curve.

The Midway deposit is unique among this group in falling well below the shale curve on the 7/4-6/4 plot while plotting above the shale curve on the 8/4-6/4 plot. The elongate Midway cluster intersects the shale curve in the Late Cretaceous on the 7/4-6/4 plot, showing good correlation of K-Ar and lead model ages. However, low Pb 207 values and an elongate data cluster with a shalower slope than error and fractionation lines suggest within deposit mixing between a shale curve - type and low μ and thorium enriched lead source. Poor elongation of the data cluster on the 8/4-6/4 plot may be due to swamping of Pb 208 from one of the lead sources, or to the mixing line being subparallel to the growth curves. In any case, mixing involving a low μ , high ω source is suggestive of lower crustal input, perhaps derived from the intrusion.

Despite some scatter, lead data from the Ketza River camp shows reasonable correlation of shale curve model ages and K-Ar dating. The Ketza cluster intersects the shale curve at a mid - Tertiary age, indicating a slghtly more radiogenic environment than that represented by the shale curve at $\sim$60 Ma. No elongation of the Ketza data cluster is apparent; within deposit mixing is therefore unlikely. Lead data from the YP and Fiddler deposits indicates a highly radiogenic lead source. This may be due to local deviation of μ and ω values in PCP stratigraphy from shale curve averages, or ~~may be due~~ to input of highly radiogenic lead from an upper crust - contaminated intrusive source. The linear trend of YP data on the 7/4-6/4 plot is suggestive of the latter, as the slope is subparallel to the Midway trens.

Earlier interpretation of PCP lead data by Dawson et al.(1986) described a Tertiary mixing line isochron due to variable upper crustal contamination of melts from which lead was derived. There are several problems with this model. First, available radiomentric dating of intrusions and alteration associated with these deposits indicates that they are related to three periods of mineralization spanning 100 to 50 Ma. A mixing line model relating all of the Rancheria - Ketza deposits to a single mixing event therefore obscures the differences in age of mineralization among the deposits. Second, while within deposit mixing has a mixing mechanism in the migration of hydrothermal fluids through different source terranes, a mixing line model for the whole of the PCP has no real mechanism, relating as it does, deposits spread over a huge area, in different lithotectonic settings, and with different ages of mineralization. Third, the slope of the PCP mixing line is actually not very different from the slope of the shale curves, and the spread of deposits along it is actually due to normal lead growth within the PCP, which is a major source terrane for these deposits. Fourth, no analogous mixing line is discernable on the 8/4-6/4 curve. As pointed out above, this may be explained in two ways: (1) the bulk of thorogenic lead is derived from one of the sources, thus swamping out development of linear trends, (2) the mixing line is actually subparallel to growth curves for lead in the relevant source terranes. The latter point applies only if there is in fact a linear trend, which is not the case for Rancheria - Ketza deposits as a group. Fifth, the end points of the mixing line would have to lie beyond the data clusters for the most radiogenic (YP) and least radiogenic (Midway) deposits. The PCP mixing line requires for example, that data for Midway be explained in terms of mixing from a highly radiogenic source whose lead ratio lies above and to the right of the YP deposit, when the actual Midway lead signature bears no relation to such a source. Finally, the PCP mixing model implies that the sources of lead are the intrusions. While some lead may be of magmatic derivation, widespread alteration haloes in siliciclastic strata of the PCP in the vicinity of many of these deposits implies that fluid - country rock interaction was extensive, and that much of the lead in these deposits was probably derived from the PCP.


15.9
5.8
.7
.6
17.5
18.0
18.5
19.0
19.5
Contact
Mixing??
72Ma
DZone
Cassiar
AgPbZn(72Ma)
Wolf
Ketza
Rancheria - Ketza
Ag-Pb-Zn (Au)
(105-50Ma)
YP
Fiddler
McDame Belle
Weisman
~50Ma
CMC
Now
Old
Silverknife
A&B
MatCr.
Logtung
Cusac
Showing
Amy
Hundere
95Ma
Sunset
Erickson
Angie
McRidge
Langer
Bay 2
Midway
MatCr.
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McRidge
Blue
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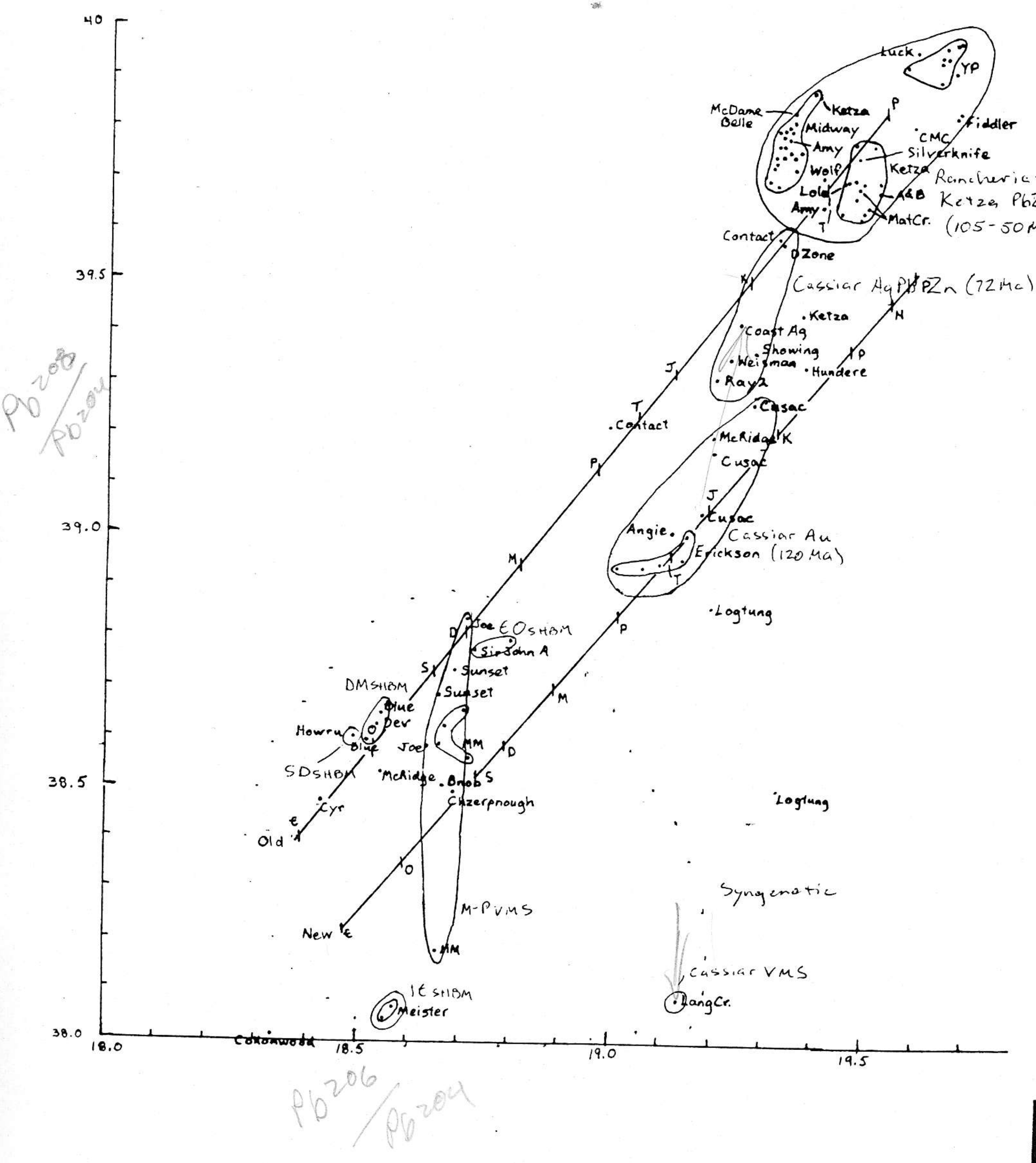

40
39.5
39.0
38.5
38.0
18.0
18.5
19.0
19.5
Pb208/Pb204
Pb206/Pb204
Luck
YP
McDame Belle
Ketza
Midway
Amy
Wolf
Lola
Amy
Fiddler
CMC
Silverknife
Ketza
A&B
MatCr.
Rancheria-Ketza PbZnA (105-50Ma)
Contact
O Zone
Cassiar AgPbZn (72Ma)
Ketza
Coast Ag
Showing
Weisman
Ray2
Hundere
Casac
Contact
McRidge
Cusac
Cusac
Angie
Erickson
Cassiar Au (120 Ma)
Logtung
Joe
EOSHBM
Sir John A
Sunset
Sunset
DMSHBM
Blue
Dev
Howru
Blue
Joe
MM
SDSHBM
McRidge
Brob
Chzerpnough
Cyr
Old
New
M-PVMS
MM
Logtung
Syngenetic
Cassiar VMS
LangCr.
IESHBM
Meister
Cottonwood

Table ?

Tectonic Element	Deposit (*)	Deposit Type	Host Lithology
North America (Pelly-Cassiar Platform up to late Devonian)	Midway (R)	Ag manto	mD carbonate
	Amy (R)	Ag manto/skarn	[illegible] carbonate
	YP (R)	Ag Au manto	lЄ carbonate
	Fiddler (R)	Sn greisen, vein	lЄ carbonate, pt
	CMC (Silver Hart) (R)	Ag vein/manto	mK qt monz., lЄ carbonate
	Silverknife (R)	Ag	lЄ carbonate
	Ketza River (P)	Au, Ag manto/skarn	lЄ carbonate
	Contact (C)	Ag skarn	Had-Є carbonate
	Coast Ag (C)	Ag	
	McDame Belle (C)	Ag vein/skarn	lЄ carbonate
	Weisman (C)	Ag vein	lЄ carbonate
	D Zone (C)	Ag skarn	lЄ carbonate
	Dead Goat (C)	W-Cu-Zn-Mo skarn	lЄ carbonat
	Luck (R?)		
	A & B (Luck) (R)	Ag replacement	lЄ carbonat
	Lola (R)	Ag vein	mK qt mz
	Wolf (R)	Zn-Pb replacement ? vn?	lЄ schist
	Angie (P)	Zn-Ag vn	SD? ls, sh.
	Meister (R)	Zn-Pb SHBM	lЄ phyllite
	Cyr (P)	?	?
	Howru (P)	Pb SHBM	S-D qtzt
Faro	{ Sunset (Fargo)	?	?
	{ Dev	?	?
Faro	Sir John A (P)	Zn SHBM	ЄO? pllt, sc
	McRidge	?	?

* Area: Cassiar - C, Randeria - R, Pelly Mtns - P
(104 P 4, 5, 12) (104O16, 105B) (

North America (Earn Group)	MM (P)	VMS	M-Penn trachyte
	Brob (P)	VMS	M-Penn trachyte
	Chzerpnough (P)	VMS	M-Penn trachyte
	Joe (P)	VMS	M-Penn trachyte
	Blue (C)	SHBM	M clastics
	Mat Crk (P)	Vein ?	M-Penn trachyte
Sylvester (Oceanic)	Erickson (C)	Au-Qt vein	M-P ? basalt
	Cusac (C)	Au-Qt vein	M-P ? basalt
	Long Creek (C)	VMS	M ? basalt

Pb Isotope References

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