

Final Report to Aberfoyle Resources Ltd, Pb
 ISOTOPE RESEARCH: Hellyer Deposit, Que River
 Aberfoyle Resources Limited*
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Pb ISOTOPE RESEARCH: Hellyer Deposit, Que River Deposit, Elliott Bay and Mackintosh District Prospects, and VHMS Source-Rock Study

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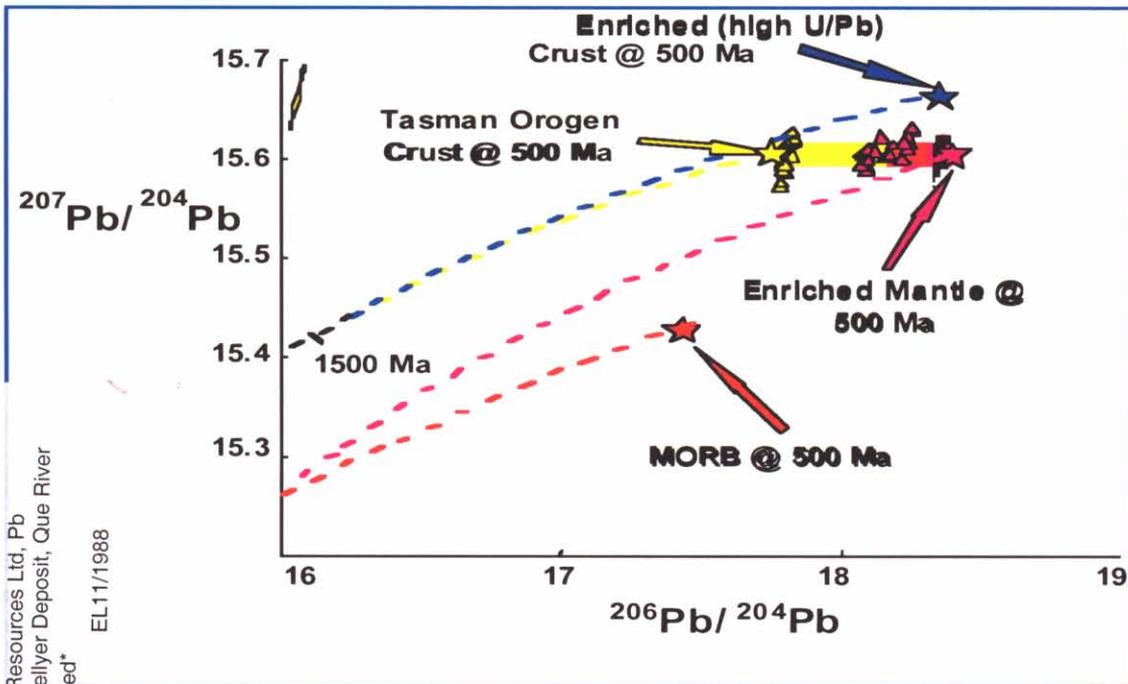
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EXECUTIVE SUMMARY

Hellyer

- Sulphides from Stage 2A and 2B veins from the Hellyer stringer and stringer envelope zones have been re-analysed and indicate a single population within the analytical precision. Low Pb samples show radiogenic addition of ^{206}Pb . Lead isotopic composition of the Hellyer massive sulphide mineralisation is very uniform.

Que River

- All the Que River data, except for the deep stringer zone, plot in the Que River target signature. Some of the deep stringer zone samples are similar to the Hellyer signature but others are very radiogenic.

- Overall the Que River data is not as homogeneous as the Hellyer data. Que River is a smaller hydrothermal system and the ore forming fluid is less homogeneous than the larger Hellyer mineralising system.

Target Signatures

- The new Hellyer and Que River data has resulted in a redefinition of the target (95% confidence ellipse) for both deposits. They are now more tightly constrained.

Mackintosh Lease Prospects

- Galena from a small base metal occurrence in the Hellyer basalt (HL 69a) above the Hellyer deposit has the same Pb isotopic signature as the Hellyer deposit.

- Galena in a Devonian fault near the tailings dam have Pb isotope ratios identical to the Que River target signature, indicating that VHMS

mineralisation similar to Que River may occur at depth below the tailings dam.

- Sphalerite in the dolerite unit near Mt Charter and disseminated sulphides in altered fragments of andesite breccia at the transition from the lower basalt to the feldspar-phyric sequence south of Que River have Pb isotope ratios that plot within the Que River target signature ellipse.

- Sulphide clasts within volcanoclastics at the Switchback plot within both the Hellyer and Que River target signature ellipses, with the majority having the Hellyer signature.

- Barite veins, sulphide-carbonate veins in andesite lavas and sulphide-carbonate veins in basaltic lavas at Mt Charter plot within or near the edge of the Que River target signature.

Newton Creek Spillway Clasts

- Sulphide-rich clasts from the Newton Creek spillway have two distinct populations, one within the Hellyer target signature and one within the Que River target signature.

- From rim to core within the clasts there is an apparent subtle range from lower to higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. The most reasonable explanation is that late relatively high $^{206}\text{Pb}/^{204}\text{Pb}$ fluids reacted *in situ* with the sulphide clasts.

Elliott Bay

- The Elliott Bay data form four distinct clusters (Groups A-D). Group A is the least and identical to the Voyager 19 stratiform massive sulphide lenses. Group B is slightly more radiogenic and has the same Pb isotope ratios as the Voyager 2 style of mineralisation. Group C

have the same Pb isotope ratios as Voyager 9 and Voyager 34. Group D is the most radiogenic cluster and has Pb isotope ratios similar to Voyager 24, 31 and 33.

Source Rock Study

- Precambrian mafics can be divided into two end members; samples with high $^{207}\text{Pb}/^{204}\text{Pb}$ ratios (termed high μ group) and samples with low $^{207}\text{Pb}/^{204}\text{Pb}$ ratios (termed low μ group). The *high μ group* has Pb ratios similar to the massive sulphide mineralisation and these rocks could possibly have supplied Pb to the hydrothermal fluids during the Cambrian. The *low μ group* however, are most unlikely to have been a source of Pb to these fluids.
- Precambrian metasedimentary rocks and Crimson Creek Formation are unlikely to have been major sources of Pb for the hydrothermal fluids.
- The average Pb in the magma sources of the Cambrian intrusives had the same Pb isotopic composition as the Pb in the hydrothermal fluids responsible for deposition of the massive sulfide mineralisation.
- Central Volcanic Complex rocks probably had initial Pb isotope ratios similar to the Cambrian intrusive rocks and/or the Que-Hellyer Volcanics and thus probably represented a source of metals for the mineralisation.
- Lead data are from clinopyroxene leaches from the Hellyer Basalt and have isotopic compositions very similar to the Hellyer target ellipse
- Cambrian VHMS Pb isotope signatures of the Mt Read Volcanics are anomalous in comparison to Cambrian crustal Pb from the Tasman Fold Belt system to the north. Gulson et al (1990) suggested that the anomalously high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios result from derivation of Pb from Precambrian crust relatively enriched in U relative to "average crust". The metallogenic and exploration significance of this model is that the ore fluids must have derived the majority of their Pb, by analogy other ore elements, from the Precambrian crustal rocks.
- We present an alternative model that explains the anomalous character of the VHMS Pb isotopes. The high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, yet low $^{207}\text{Pb}/^{204}\text{Pb}$ ratios, for the Cambrian VHMS deposits (Rosebery, Que River, Hellyer) require a source that has evolved over a long period of time with high U/Pb ratios but with low initial $^{207}\text{Pb}/^{204}\text{Pb}$ ratios. Such a source is most likely to have been a U enriched mantle with an average isotopic composition in the Cambrian similar to, or with higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, than the Hellyer target ellipse. Mixing of this Pb with normal Tasman Orogen Cambrian crustal Pb similar to the Kanmantoo data would account for the range of $^{206}\text{Pb}/^{204}\text{Pb}$ values between the Hellyer and Elliott Bay end members.
- It is our proposal that within the overall tectonic context of the Mount Read Volcanic terrain, the association with substantially mantle derive Pb is critical to the formation of major massive sulfide mineralisation. *Therefore an exploration model that incorporated a search for the most mantle-like hydrothermal signatures in the terrain would seem to have the highest probability of success.*

Introduction

Historically, Pb isotopes have played a significant role in the evaluation of conceptual models for ore genesis and recently their use in mineral exploration has been recognised (Gulson, 1986). Lead isotopes have been used widely throughout western Tasmania since the pioneering work of Gulson and Porritt (1987) and Gulson et al. (1987). On the basis of their Pb isotope signatures they discriminated Cambrian volcanic-hosted massive sulphide deposits (Mt Lyell, Rosebery, Hercules, Que River, Hellyer) from deposits formed in response to Devonian-Carboniferous granitoid emplacement and/or Tabberabberan metamorphism (Renison Bell, Queen Hill, Farrell lodes). These groupings are the rationale for the use of Pb isotopes in mineral exploration on the west coast of Tasmania.

Lead isotope signatures of exploration prospects, in combination with a potential Pb isotope stratigraphy of the host rocks, could be used to develop a more powerful discriminant for exploration targeting. This project was undertaken by Drs Bruce Gemmill and Joe Stolz and Professor Ross Large of CODES, Dr Graham Carr and Judy Dean of CSIRO, and David Wallace, Gary McArthur, Steve Richardson, Robina Sharpe and Richard Downs of Aberfoyle Resources Ltd.

The aims of the joint CODES/CSIRO/Aberfoyle Pb isotope research project are to:

1. Re-analyse several sulphide mineral separates from selected Stage 2A and 2B veins from the Hellyer stringer zone to confirm the two signatures in the previous Pb isotope.
2. Analyse sulphide samples from the Hellyer orebody, (pyrite-chalcopyrite mound up through the barite and siliceous caps). In addition massive sulphide mineralisation occurring in the hangingwall Hellyer basalt (HL 69A) and chalcopyrite, pyrite and galena veins hosted by the Hellyer basalt will be investigated. This study will complement the existing data for the stringer zone, and document the Pb isotope signature of the Hellyer mineralising system.
3. Analyse samples from the Que River stringer zone and massive sulphide deposit.
4. Analyse samples from prospects in the Mackintosh District, Mt Charter, Switchback sulphide boulders, Murray's Road sulphide boulders and others.
5. Analyse selected Newton Creek Spillway clasts to determine if there is any internal variation of Pb isotope ratios.
6. Analyse the various styles of mineralisation from the Elliott Bay area.
7. Analyse samples of the potential source rocks (whole-rock and mineral separates) for the VHMS mineralisation throughout western Tasmania. This study will investigate Precambrian through to Devonian volcanic, sedimentary and intrusive lithologies. The previous study on the stringer zone beneath the Hellyer deposit has shown that Pb isotope data for potential source rocks for VHMS mineralisation are essential to fully understand the Pb isotopic systematics of the deposit. Lead isotope data from exploration prospects, in combination with a potential Pb isotope stratigraphy of the host rocks, could be used to develop a more powerful discriminant for exploration targeting.
8. Compile and evaluate all Pb isotope data previously obtained by Aberfoyle Resources for the Mackintosh District and Newton Creek Spillway in light of the results and information generated in this study.

Preliminary results on the Hellyer, Elliott Bay and source rock portions of this study have been reported in Gemmell et al. (1992) and Gemmell (1994).

Methods and Techniques

In total, 43 sulphide samples from the Elliott Bay, 32 samples from the Hellyer VHMS deposit, 11 samples from the Hellyer stringer veins, 17 samples from the Que River VHMS deposit, 30 samples from various mineralisation types from the Macintosh lease, 8 samples of sulphide clasts from the Newton Creek spillway and 31 whole-rock, with 14 feldspar and pyroxene mineral separate, samples from various lithologies throughout the western portion of Tasmania were analysed. After initial sample preparation at the University of Tasmania, JBG spent a total of nine weeks at the CSIRO laboratory (November-December 1991, November-December 1994, June 1994) performing chemical separation and analytical work, including mass spectrometry on these samples under the direction of Graham Carr, Judy Dean and Barbara Gardner.

Sulphide and whole-rock sample preparation followed standard chemical separation techniques. Sulphides were hand picked or drilled out of drill core or hand samples with galena being the dominant phase. Subordinate amounts of sphalerite and pyrite occurred in some samples. Galena was dissolved in concentrated HNO_3 and purified by electroplating onto Pt electrodes using micro-electrode position techniques. Mixed sulphide samples were dissolved in a hot 1:1 mixture of 7N HCL and 7N HNO_3 with a few drops of concentrated HBr. Lead was extracted by anion exchange methods in dilute HBr solutions and purified as for the galenas.

Whole-rock samples of possible/potential source rocks were analysed from crushed powders collected by Dr Joe Stolz as part of the AMIRA project in the late 1980s. An approximately 50-100 mg sample of rock powder was weighed into a Savillex beaker

along with a known amount of ^{202}Pb spike, in order that the Pb content could be determined simultaneously with Pb isotope ratios by isotope dilution techniques. The samples were digested in the same acid "cocktail" as for the mixed sulphide samples. Lead was extracted and purified using double anion exchange columns.

Eight of whole rock samples were selected for HF leaching of the residual component from the first dissolution. After addition of a known amount of ^{202}Pb spike, the samples were digested in HF with a few drops of concentrated HNO_3 . These samples were then treated in a similar fashion to the whole rock samples.

Potassium feldspar and pyroxene mineral separates were analysed to determine the initial Pb isotope ratios of selected volcanic and intrusive rocks. The minerals were analysed by a sequential leaching technique involving initial partial dissolution in a 7N HCl + 7N HNO_3 solution followed by washing and final total dissolution of the residual mineral in HF + HNO_3 .

Lead ratios were determined using a VG Isomass 54E solid source mass spectrometer run in fully automated mode at the CSIRO Division of Exploration and Mining, North Ryde, NSW. The Pb isotope extractions and analyses were performed by Bruce Gemmell, Judy Dean, Barbara Gardner and Graham Carr. Lead isotope data has been normalised to the accepted values of international standard SRM NBS981 by applying a correction factor of 0.08% per atomic mass unit. Precision estimates, based on over 1300 analyses of international standards and natural samples, are shown as error bars (mean \pm 2s) in the upper left hand corner of many of the accompanying diagrams. Also shown are the 95% confidence ellipses for these standard data.

Results

The results of this study will be broken into two parts. Part 1 will deal with the sulphide lead isotope results from the investigation of the

Hellyer, Que River, Elliott Bay, Mackintosh District prospects and Newton Creek spillway clasts. Part 2 will discuss the relationship of hydrothermal and magmatic Pb isotope signatures of the source rocks throughout the Western Tasmanian stratigraphy.

Part 1

Mineralisation Signatures

1.1 Stringer Vein Trends

A detailed Pb isotope study of the vein mineralisation in the stringer zone underlying the Hellyer volcanic-hosted massive sulphide deposit was conducted by Gemmell (1990). This study illustrated variations in Pb isotope ratios between the different types of syn-mineralisation veins in the stringer system. Syn-mineralisation veining in the stringer zone is divided into three stages (Gemmell 1988; Gemmell and Large, 1992): early quartz-pyrite-carbonate veins (Stage 2A), base-metal-rich veins (Stage 2B), which are the veins responsible for carrying the metal-rich solutions to the seafloor and precipitation of the Hellyer deposit, and later barite-rich veins (Stage 2C). The Pb isotope data for the Stage 2B veins had the same ratios as the signatures for the Hellyer and Que River massive sulphide deposits, but Pb isotope data for the Stage 2A pyrite-rich veins, from both the stringer and stringer envelope zones, had distinctly higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios (Table 1.1 and Fig. 1.1).

Eleven sulphide separates from selected Stage 2A and 2B veins from the Hellyer stringer and stringer envelope zones have been re-analysed and the data is presented in Table 1.1. Seven samples of Stage 2A veins in the stringer envelope zone (SEZ) were re-analysed to verify their high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. Graham Carr expressed concern that the high $^{206}\text{Pb}/^{204}\text{Pb}$ ratio Stage 2A data could be the result of addition of radiogenic Pb since the Cambrian from the decay of U in low Pb-bearing pyrite in these veins. The Pb contents of these samples are low (63-1700 ppm), indicating that radiogenic addition of Pb is likely to have occurred. Re-analysis of three high Pb (1610-4720 ppm) Stage 2A veins in the stringer zone shows that they have very similar Pb isotope ratios to the Stage 2B veins.

Re-analysis of seven samples from the

Stage 2B trend was carried out to confirm their signature. Figure 1.2 shows the re-analysed data compared to the original data. The high $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios of the original (Dartmouth College) data from the 2B trend are not duplicated by the re-analyses, all of which plot within a 95% confidence ellipse previously defined for Hellyer based on CSIRO analyses. This confirms that the previously defined "2B trend" is in fact within the error limits of the analytical procedure and thus represents an analytical mass fractionation. In summary, the new data confirm a homogeneous signature for Hellyer high-Pb samples and that the previously described variations (Gemmell, 1990; Gemmell et al., 1990) are not real.

Pb isotope signatures for the major mineral deposits on the west coast of Tasmania allowed Gulson and Porritt (1987) to discriminate two contrasting styles of mineralisation; Cambrian VHMS deposits and deposits related to Devonian-Carboniferous granitoids and/or Tabberabberan metamorphism. Pb isotope ratios for both the syn-mineralisation Stage 2A and 2B veins extend from the Cambrian volcanic-hosted mineralisation field into the granite-related Devonian mineralisation field (Fig. 1.3). Results of this study suggest that care must be taken when interpreting the results from VHMS stringer systems. Depending on the nature of the mineralisation sampled, a highly radiogenic Pb isotope ratio could be related to a Devonian granite-related system or to the addition of radiogenic Pb in low Pb-bearing sulphides.

1.2 Hellyer Deposit

A Pb isotope investigation of the Hellyer deposit was undertaken to determine if there is zonation in the Pb isotope signature throughout the stratigraphy of the massive sulphide mineralisation (pyrite mound up through barite

and siliceous caps). After consultation with Gary McArthur, galena or high Pb-bearing mixed sulphide samples were collected from selected drill holes of all mineralisation types throughout the Hellyer deposit.

Table 1.2 lists the samples, their location and the Pb isotope ratios. These data are plotted on standard $^{217}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams (Fig. 1.4).

Almost all the data in Figure 1.4 fall along the fractionation and ^{204}Pb error trend. These data indicate that the Pb isotope signature of the Hellyer deposit is tight and that the character of the Pb within the deposit is homogeneous. The Hellyer deposit Pb isotope ratios are nearly identical to those from the syn-mineralisation veins in the stringer zone. The two Hellyer samples that sit outside the main population (Fig. 1.4, data points 5 and 24) come from the barite or siliceous cap mineralisation.

Fehn et al. (1983) documented differences in Pb isotope values with stratigraphic height in the Kuroko deposits of the Hokuroku district, Japan. They reported that the black ore was significantly higher in radiogenic lead compared to the yellow ore. From the distribution of values in the Hellyer data (Fig. 1.4) there does not appear to be any difference in Pb isotope values between the massive pyrite mound or footwall depleted mineralisation (equivalent to the kuroko yellow ore) and the hangingwall enriched ore (equivalent to the kuroko black ore).

1.3 Que River Deposit

Galena and pyrite samples from the massive sulphide, stringer zone, precious-metal bearing stringer zone and the deep stringer zone at Que River were analysed to determine the variability within the Que River system as compared to Hellyer and to try to determine why Que River has a different Pb isotope ratio from Hellyer as reported by Gulson and Porritt (1987).

Table 1.3 lists the samples, their location and the Pb isotope ratios. These data are plotted on standard $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and

$^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams (Fig. 1.5). All samples from the massive sulphide, stringer zone and precious-metal bearing stringer zone (STZ-Au) are galenas except for one stringer zone sample which was pyrite. All the samples from the stringer zone are pyrite. Pb values for the pyrite samples are given in Table 1.3.

Data in Figure 1.5 shows that the massive sulphide samples, with one exception, plot in the Que River target signature (which is comforting!). The other sample plots in the Hellyer field. Two of the three stringer zone samples plot in the Que River field while one, which is a galena, plots in the Hellyer field. Both samples from the precious-metal bearing stringer zone plot in the Que River field. None of the samples from the deep stringer zone plot in the Que River field, however four of the seven plot in, or close to, the Hellyer field and the remaining three are very radiogenic, with $^{206}\text{Pb}/^{204}\text{Pb}$ values greater than 18.45 (Fig. 1.5). These three samples, all of which are pyrite, have Pb values of 420, 1070 and 1840 ppm respectively. The sample with 420 ppm Pb ($^{206}\text{Pb}/^{204}\text{Pb} = 18.484$) may represent a radiogenic shift since time of precipitation but the other two sample have values of 1070 ppm Pb ($^{206}\text{Pb}/^{204}\text{Pb} = 18.526$) and 1840 ppm Pb ($^{206}\text{Pb}/^{204}\text{Pb} = 18.722$) are probably initial ratios. These two values are consistent with Pb signatures from Devonian mineralisation found throughout the Mount Read Volcanics as reported by Gulson and Porritt (1987). These two samples come from veins that appear to be no different than the typical Cambrian stringer veins and are likely to represent Devonian veins that are cross cutting the deep stringer zone.

Overall the Que River data is not as homogeneous as the Hellyer data, in that several of the galena or high lead pyrite samples plot outside the Que River BMS target signature. This may be due, in part, to the fact that Que River is a smaller system and the ore forming fluid is less homogeneous than the larger Hellyer mineralising system. The variation (more radiogenic) in the Pb isotope values for the stringer zone, precious-metal bearing stringer

zone and the deep stringer zone is due to some samples being low lead but primarily due to slight differences in fluid composition during the mineralising process. These differences are likely due to variations in the source rocks these fluids have encountered before being focused to the site of mineral deposition.

1.4 Target Signatures

The results obtained in this study led Carr and Dean (1992) to revise the target signatures (5% confidence ellipses) for the massive sulphide mineralisation at Hellyer. The Que River target signature has also been revised on a reappraisal of the available data from Que River (Carr and Dean, 1992).

The Hellyer data obtained in this study, when combined with the existing data reported in Gulson and Porritt (1987), indicate a much more homogeneous Pb isotope population than previously defined. The new target signature has been determined by eliminating two points from the Gulson and Porritt's (1987) data and one of the data points obtained in this study, all of which have significantly lower $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. These three data points are considered to be part of a different population (Carr and Dean, 1992). Figure 1.6 shows a comparison of the old and new target signatures for Hellyer and Que River. All Pb isotope diagrams in this report use the re-defined target ellipses for comparison purposes.

1.5 Mackintosh District Prospects

Occurrences of sulphide and barite mineralisation throughout the Mackintosh District was examined to see how, or if, they relate to the known mineralising systems at Hellyer and Que River. Sulphides from various styles of mineralisation throughout the Mackintosh District (the Switchback sulphide boulders, Murray's Road sulphide boulders, D Zone), including Mt Charter were collected with the help of Dave Wallace, Steve Richardson, Gary McArthur and Richard Downs.

Table 1.4 lists the data from various occurrences of pyrite and base metal sulphides throughout the Macintosh lease. Galena from a small base metal occurrence in the Hellyer basalt above the Hellyer deposit (HL 69a - "Hellyer in a core tray") has the same Pb isotopic signature as the Hellyer deposit (Fig. 1.7). These data indicate that this mineralisation is related to the main Hellyer hydrothermal system and represents a continuation of the mineralising fluids through the capping Hellyer basalts. Samples of chalcopyrite in the Hellyer basalt from the 75-84 South Drive on the 495 m level of the mine contain very low levels of lead (Table 1.4) and have very unusual Pb isotopic ratios. The sample with only 37 ppm Pb has a very radiogenic value as would be expected but the sample with 229 ppm Pb has the least radiogenic signature of the samples analysed.

Galena in a fault near the tailings dam (Table 1.4; Fig. 1.8) have Pb isotope ratios that plot within the Que River target signature ellipse. This galena appears to be remobilised into a Devonian structure and the Pb isotope signature may indicate that VHMS mineralisation similar to Que River may occur at depth below the tailings dam.

Sphalerites in the dolerite unit near Mt Charter (MAC 14 and 27 - Table 4; Fig. 1.9) have Pb isotope ratios that plot within to slightly outside the Que River target signature ellipse. Disseminated sulphides in altered fragments of andesite breccia at the transition of the lower basalt to the feldspar phyric sequence (MAC 29) south of Que River also have Pb isotope ratios that plot within the Que River target signature ellipse. These data suggests that both these occurrences of sulphides were precipitated from fluids similar to the Que River mineralising system.

Samples SB1- SB6 and the MLB series represent clasts of base metal sulphides within the polymict basaltic breccia at the base of the mixed sequence just above the feldspar phyric sequence. These samples were collected in 1985 when road construction exposed them

between Que River and the Switchback. The Pb isotope ratios for these high Pb-bearing clasts (Table 1.4; Fig. 1.10) plot within both the Hellyer and Que River target signature ellipse, with the majority within the Hellyer ellipse. Galena from a sulphide clast in a polymict basalt at the Kimba Trench (MAC 9 - 5400 E, 8600N) (Table 1.4; Fig. 1.10) plots within the Hellyer target ellipse. Galena from a sulphide clast in a polymict basalt breccia from MAC 9 (5700 E, 8600N) (Table 1.4; Fig. 1.10) plots near the edge of the Que River target ellipse. A galena-bearing sulphide clast from the Switchback from the epiclastic unit (Y-BV) at the top of the mixed sequence has Pb isotope ratios that plot within the Que River target ellipse. Samples MLB 1 (Table 1.4; Fig. 1.10) are galena-bearing sulphide clasts within the epiclastic unit along strike west of the Switchback at 8900 N. These samples have Pb isotope ratios that plot within the Hellyer target ellipse. All the data from the sulphide clasts that occur between Que River and Hellyer suggest that these clasts were sourced from 1) both the main Que River and Hellyer deposits and transported via submarine debris flows or 2) sourced more locally to their site of deposition from separate, small, satellite mineralising systems that had fluids similar to both Que River and Hellyer

Data previously collected for Mt Charter (Table 1.5) was re-evaluated as part of this project. These data include massive barite veins, sulphide-carbonate veins in andesite lavas, sulphide-carbonate veins in basaltic lavas, banded sphalerite in the HVS and C horizon soils. They are plotted on Figure 1.11. All the data from the sulphide-carbonate veins from both the andesite and basaltic lavas, except one sample, plot within or near the edge of the Que River target signature ellipse. One galena-carbonate vein in the basaltic lava has a very radiogenic signature and may represent a vein with Devonian lead. Two samples of banded sphalerite in the HVS unit at Mt Charter are relatively low lead-bearing and have very radiogenic Pb isotope signatures that plot well

to the right of the Hellyer target ellipse. The C horizon samples plot near the lower edges of both the Que River and Hellyer ellipses except for the lowest Pb-bearing sample which has a very radiogenic Pb isotope ratio and plots well to the right of the Hellyer ellipse. All the Mt Charter data suggests that the Mt Charter mineralising system contained hydrothermal fluids with the same Pb isotopic signature as the Que River system.

Four additional prospects of mineralisation around the Macintosh lease were also analysed. The data for Black Harry, Murray's Reward, Henty Fault and Boundary are given in Table 1.5 and Fig. 1.12. Galena from the Henty Fault is more radiogenic than the Hellyer target signature and may represent Devonian lead. The Black Harry and Murray's Reward pyrites are low in lead (525 and 145 ppm respectively) but plot in the Hellyer target signature ellipse. The pyrite-barite vein at Boundary contains only 225 ppm Pb and has a very radiogenic signature. This could be due to radiogenic addition of ^{206}Pb or that this vein contains Devonian lead.

1.6 Newton Creek Spillway

Carr (1992) analysed 8 sulphide-rich clasts from the Newton Creek spillway (Table 1.6). These data plotted in two distinct populations (Fig. 1.13), one within the Hellyer target ellipse and one within the Que River target ellipse. From these data it was suggested that the Pb isotope signatures of all the clasts pointed strongly to a Cambrian origin for the Pb and that the two different populations indicate that the hydrothermal fluid evolved over the period of deposition in a similar manner to the evolution at Que River and Hellyer (Carr, 1992). The Newton Creek sulphide clasts are also unique as they are the only samples of CVC mineralisation that do not contain at least some Pb with the Rosebery signature (Carr, 1992).

Two further samples of sulphide clasts from Newton Creek were analysed as part of

this study (Table 1.6). The two samples were selected for detailed sampling of galena from the rim to the core of each sample (Fig. 1.14) to see if there was any zonation of Pb isotope ratios across these samples. The results are listed in Table 1.6 and plotted on Figure 1.14. In comparison to the Carr (1992) data these samples do not plot as two distinct populations but as one continuous trend that starts in the Que River target ellipse and extends to more radiogenic ratios along the edge of the Hellyer target ellipse, apart from point rs4 in sample RS-1 which plots in the Hellyer target ellipse.

A detailed view of the Pb isotope traverses across samples BG-1 and RS-1 is shown in Figure 1.15. Sample RS-1 shows some variation from rim to core. Subsamples RS-2 and RS-3 from within the clast lie on a single fractionation trend (see dashed line in Figure 1.15) suggesting they have indistinguishable Pb isotope ratios. Subsamples RS-1, RS-5, and subsample RS-4 from the rim of the clast lie on separate trends displaced to higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. Thus there is an apparent subtle range from lower to higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios from rim to core. Similarly, subsample BG2 in the centre of clast BG lies on the same fractionation trend as RS-2 and RS-3 with BG-3 and BG-1 near the rim of the clast having slightly higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. These data lie within the total range of data discussed in Carr (1992).

This range of Pb isotope ratios is equal to greater than the range seen in both the Que River and Hellyer deposits. It indicates that the Pb isotopic composition of the fluid(s) responsible for deposition of galena in the clasts changed with time. The most reasonable explanation is that late relatively high $^{206}\text{Pb}/^{204}\text{Pb}$ fluids reacted *in situ* with the sulphide clasts.

1.7 Elliott Bay

The geology and mineralisation of the Elliott Bay prospects have previously been described by Large et al. (1987), Gulson et al. (1987) and Callaghan (1989). Mineralisation in the Elliott Bay area takes the form of sulphide clasts, stringer sulphides, disseminated sulphides,

massive sulphide lenses and sulphides associated with alteration. All mineralisation styles are hosted in deformed Cambrian felsic volcanics and volcanoclastics. As no general overview of the Elliott Bay geology will be given in this report, readers are referred to the above papers for background information.

Gulson et al. (1987) reported Pb isotope variation for the various styles of mineralisation on the surface and in two Geopeko drill holes from the Elliott Bay area. They determined that Cambrian stratiform massive sulphide mineralisation constitutes the least radiogenic group and Devonian vein style Pb-Zn-As mineralisation forms the most radiogenic group (Fig. 1.3). A third group with isotopic ratios mostly intermediate between the other two comes from disseminated and vein type Pb-Zn mineralisation related to the intrusion of a quartz porphyry that is considered to be later than the massive sulphide formation. Gulson et al. (1987) noted that clasts of massive sulphide mineralisation within submarine epiclastic breccias, interpreted to be a series of mass flows by Callaghan (1989), are different from the massive sulphide lenses. Clearly these variations in Pb isotope data from the Elliott Bay area need revision in order to better define the use of Pb isotopes for targeting.

Cyprus Minerals took over the exploration leases in the Elliott Bay in the middle to late 1980s and drilled a further 12 holes which resulted in a better understanding of the geology and mineralisation. In light of this increased geologic understanding, sulphide samples of the differing styles of mineralisation from the Cyprus drilling at Wart Hill were collected and analysed. Samples from a mineralised zone discovered by Aberfoyle Resources Ltd in early 1992 were also analysed.

Table 1.7 lists the Pb isotope data for the Elliott Bay samples analysed in this study. These data are plotted on standard $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams (Fig. 1.16). For comparison the previous Pb isotope data for Elliott Bay from Gulson et al. (1987) and previously unpublished results from

SIROTOPE's files are shown in Figure 1.17.

The new Elliott Bay data form four distinct clusters (Fig. 1.16; Groups A-D). Group A consists primarily of galena-sphalerite clasts and is the least radiogenic. These clasts have a lead isotopic signature identical to the Voyager 19A and 19B stratiform massive sulphide lenses.

Group B also consists of sphalerite-galena clasts but is slightly more radiogenic than the Voyager 19 massive sulphides. Group B clasts have the same Pb isotope signature as the Voyager 2 style of mineralisation (disseminated and fracture galena coatings in volcanoclastic units) (Fig. 1.17).

Group C consists of disseminated, vein and alteration-hosted galena, sphalerite and pyrite. These styles of mineralisation have the same Pb isotope signature as Voyager 9 (chlorite-magnetite alteration) and Voyager 34 (soil geochemical anomaly) (Fig. 1.17).

Group D is the most radiogenic cluster and contains disseminated and vein sulphides (mostly galena) that are clearly younger (based on core logging) than all the previous styles of mineralisation. This cluster has a Pb isotope signature similar to Voyager 24 (vein-style galena and sphalerite) and Voyager 31 and 33 (galena-sphalerite-arsenopyrite veins) (Fig. 1.17).

Several mineralised samples, and two soil samples, from a new altered and mineralised area discovered during Aberfoyle's 1992 exploration program were analysed by SIROTOPE. These results are given in Table 1.7. All of the exploration samples (except 5655530 and 565576) plot in the Group C field. Samples 5655530 and 565576 plot between the Group B and C fields.

The Pb isotope data from the Elliott Bay mineralisation plots in distinct groups that are related to the style of mineralisation (Fig. 1.16). Massive sulphide lenses (Voyager 19) and sulphide clasts of Groups A and B appear to have formed from a Pb source that was significantly different from the Pb in Groups C and D mineralisation. The spread in $^{206}\text{Pb}/^{204}\text{Pb}$ ratios for mineralisation in the Elliott Bay area is greater than the spread between Cambrian

and Devonian mineralisation throughout the west coast of Tasmania (Fig. 1.3) as proposed by Gulson et al. (1987).

From the geology, alteration and Pb data, a preliminary model is proposed to explain the mineralisation at Elliott Bay (Fig. 18). In the Cambrian, a VHMS deposit (Voyager 19 and Group A and B-type mineralisation), of unknown size, formed on the seafloor somewhere in the vicinity of the Wart Hill area. Shortly after the deposit formed, subaqueous debris flows incorporated fragments of this mineralisation and deposited them at the present site of Wart Hill. These fragments became one of the clast types in the debris flow deposits. Shortly after the deposition of the debris flows, and other "hangingwall" lithologies, a separate generation of hydrothermal fluids (still in the Cambrian?) passed through these rocks causing alteration (sericite, silica, chlorite, minor carbonate) and precipitation of disseminated and stringer sulphide mineralisation (Group C). Much later, possibly in the Devonian, another generation of hydrothermal fluids passed through the rocks causing minor alteration and sulphide mineralisation (Group D galena-sphalerite-arsenopyrite veins).

Gulson et al. (1987) proposed a multi-stage model, based on Pb isotope data, implying that the ultimate source of Pb in the Cambrian stratiform sulphide mineralisation at Elliott Bay, was from the Precambrian basement (Fig. 1.19). As the Pb isotope ratios of massive sulphide mineralisation at Elliott Bay are distinctly less radiogenic than those from Que River and Hellyer, Gulson et al. (1987) suggested a variation in the U-Th-Pb characteristics of source regions, with a northward increase in U/Pb from Elliott Bay to Que-Hellyer, or the possibility of different ages for the separate mineralising systems along the Mt Read Volcanic Belt. Gulson et al. (1987) postulated that the volcanic pile and underlying basement exhibit a vertical variation in U/Pb ratio and that solutions penetrating to different depths would concentrate Pb with different isotopic ratios.

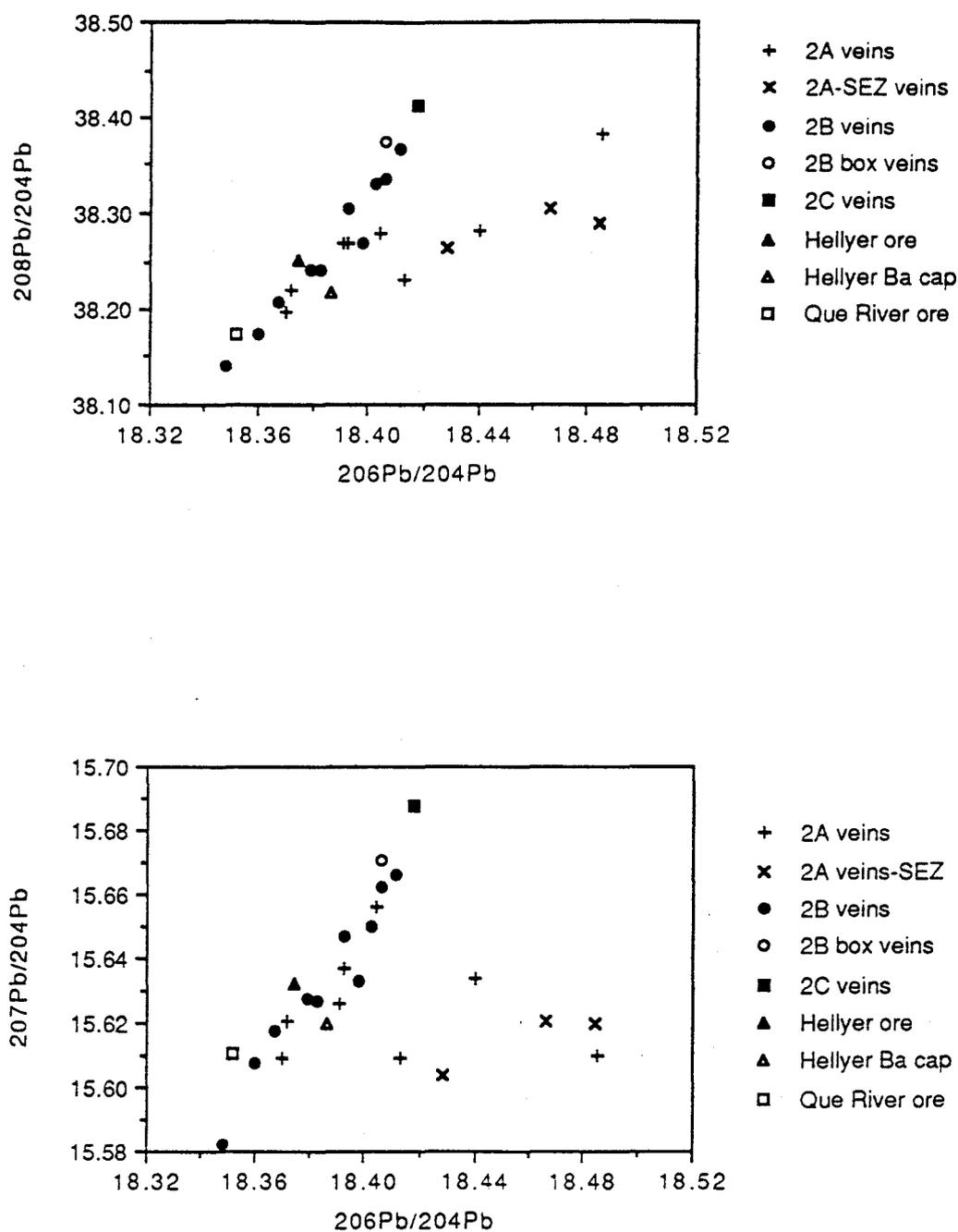


Figure 1.1

Pb isotope data for the veins in the Hellyer stringer zone on $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Gemell (1990). These diagrams suggested that there are variations in Pb isotope ratios between the types of syn-mineralisation veins in the stringer zone. Stage 2B veins have the same signature as the Hellyer and Que River massive sulphide deposits, but the Stage 2A veins, from both the stringer and envelope zones, have more radiogenic Pb isotope ratios.

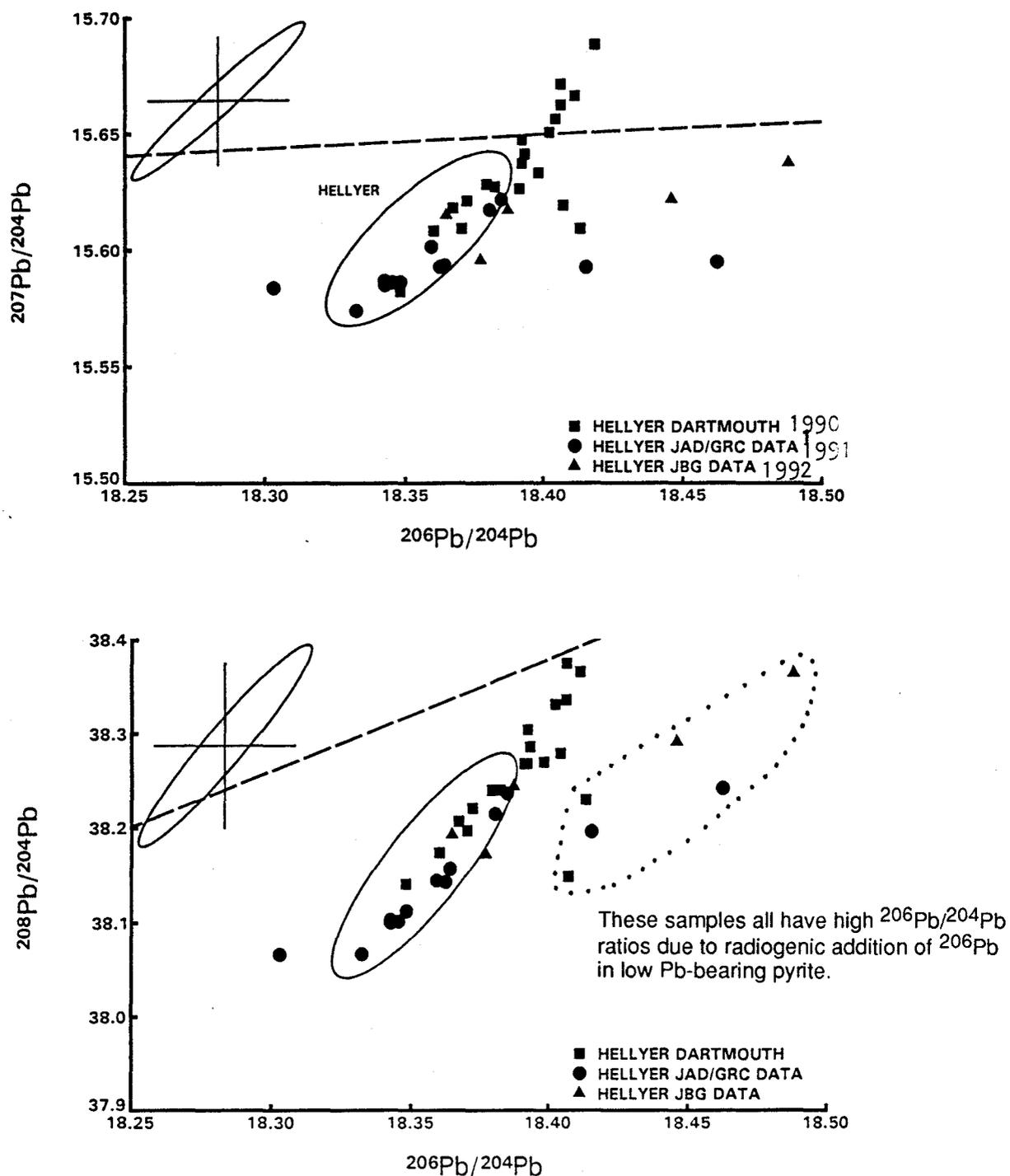


Figure 1.2

Re-analysed Pb isotope data for the syn-mineralisation veins in the Hellyer stringer zone on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from table 1.1. The re-analysed samples demonstrate that the variations in Pb isotope ratios in the Stage 2A and 2B are an artifact of radiogenic addition of Pb in the low Pb-bearing samples. The Pb evolution curve (growth curve) of Cumming and Richards (1975) is shown for reference.

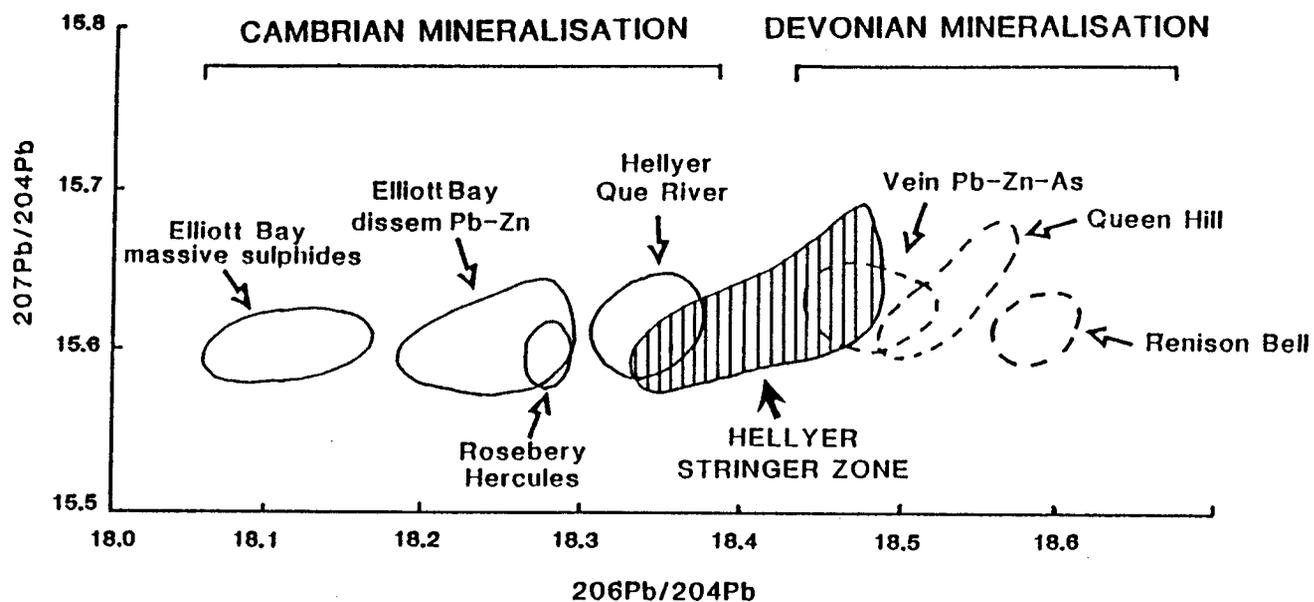


Figure 1.3

Pb isotope data for Western Tasmanian mineralisation (after Gulson et al., 1987). Note that the Pb isotope data from the Hellyer stringer zone extends from the Cambrian mineralisation field into the Devonian mineralisation field.

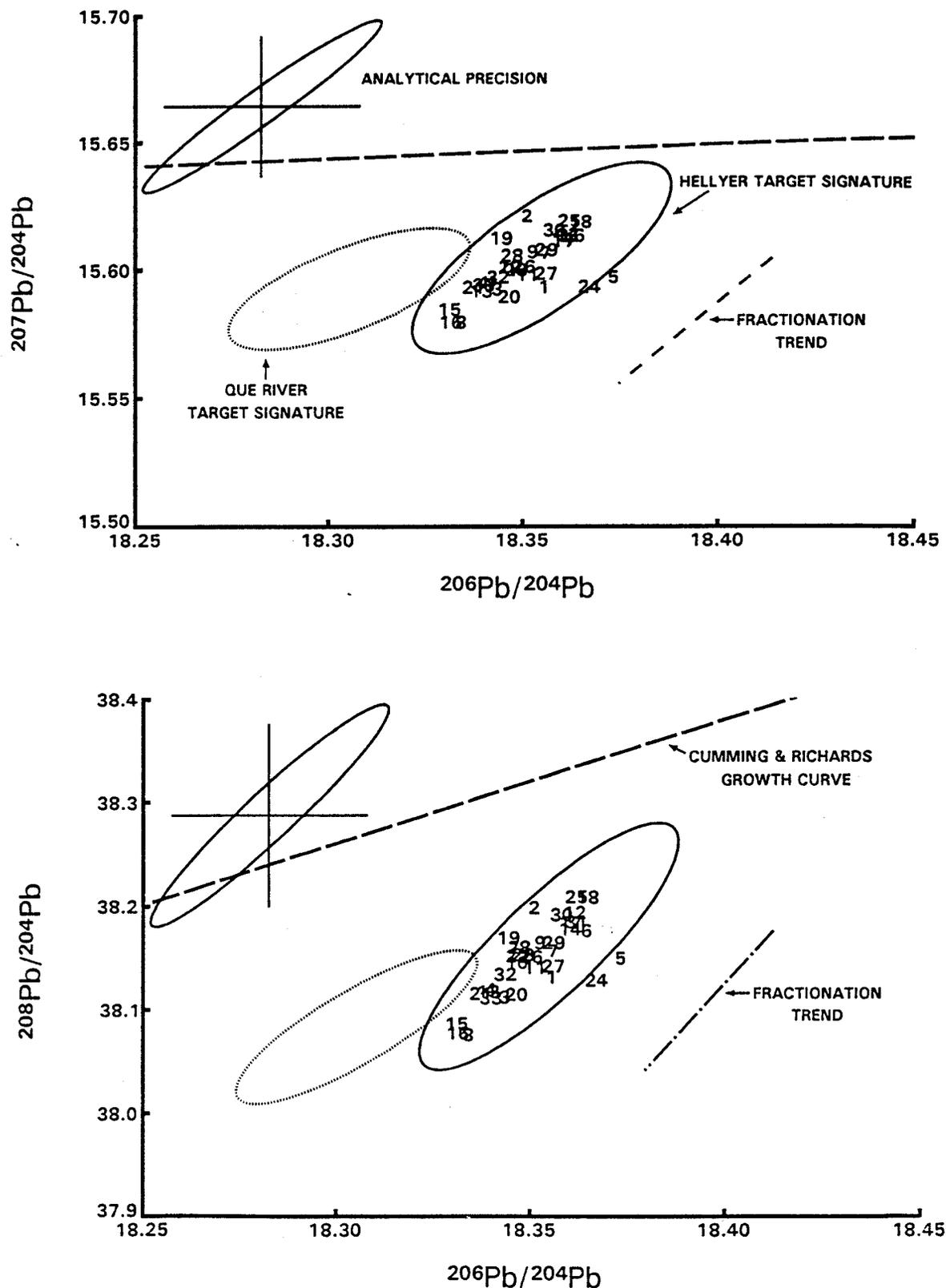


Figure 1.4

Pb isotope data for the Hellyer massive sulphide mineralisation on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. sample numbers refer to plot # in Table 1.2. Almost all the Hellyer data falls along a ^{204}Pb fractionation trend indicating that it has a homogenous signature. The two sample points (5 and 24) are from the barite and siliceous caps. The reasons that points 5 and 24 differ from the massive sulphide are discussed in the text.

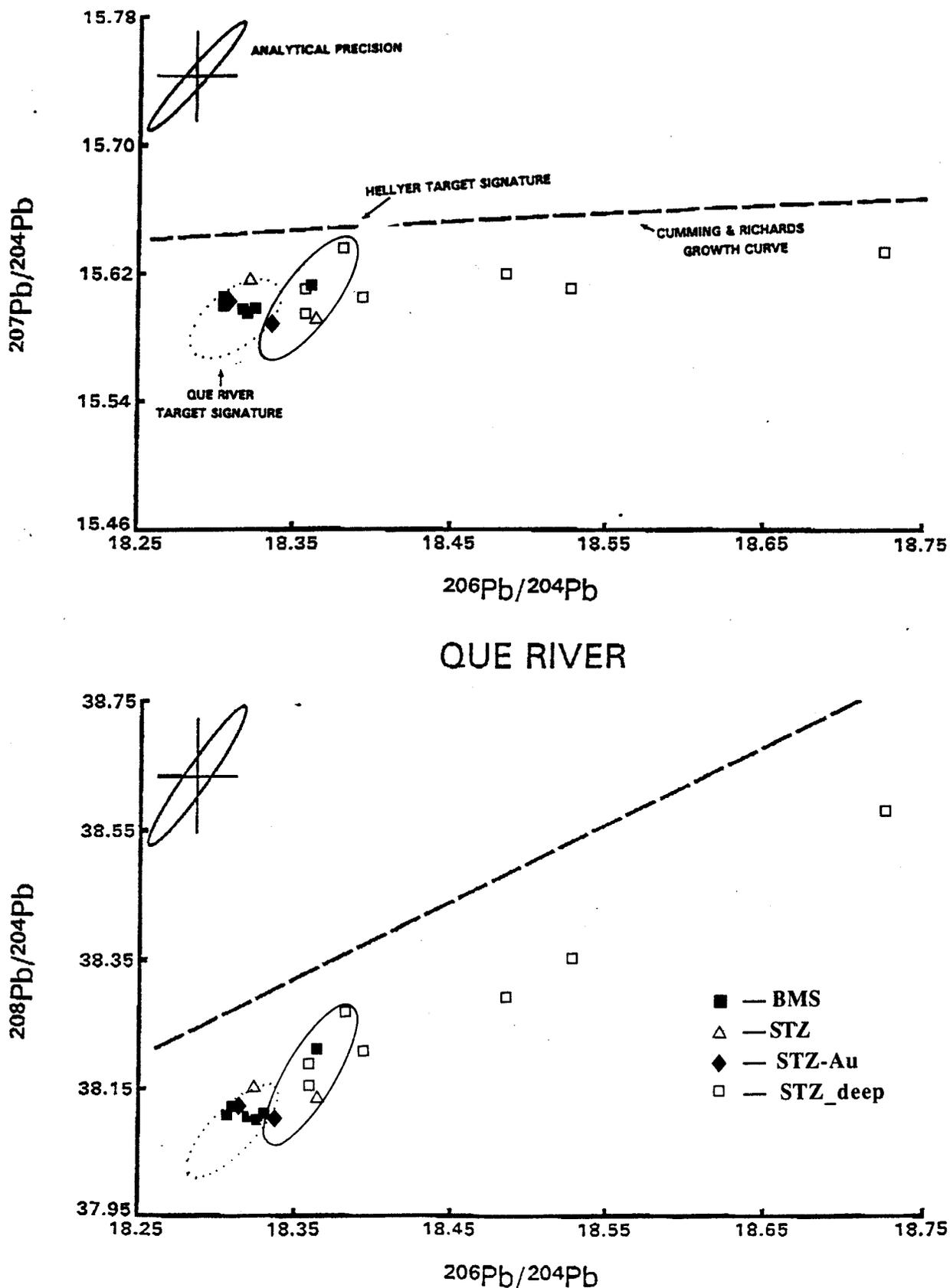


Figure 1.5

Pb isotope data for the Que River massive sulphide and stringer mineralisation on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.3. Abbreviations: BMS - base metal sulphide, STZ - stringer zone galena, STZ-Au - precious metal zone galena in the footwall, STZ-deep - stringer sulphides (pyrite) deep in the footwall.

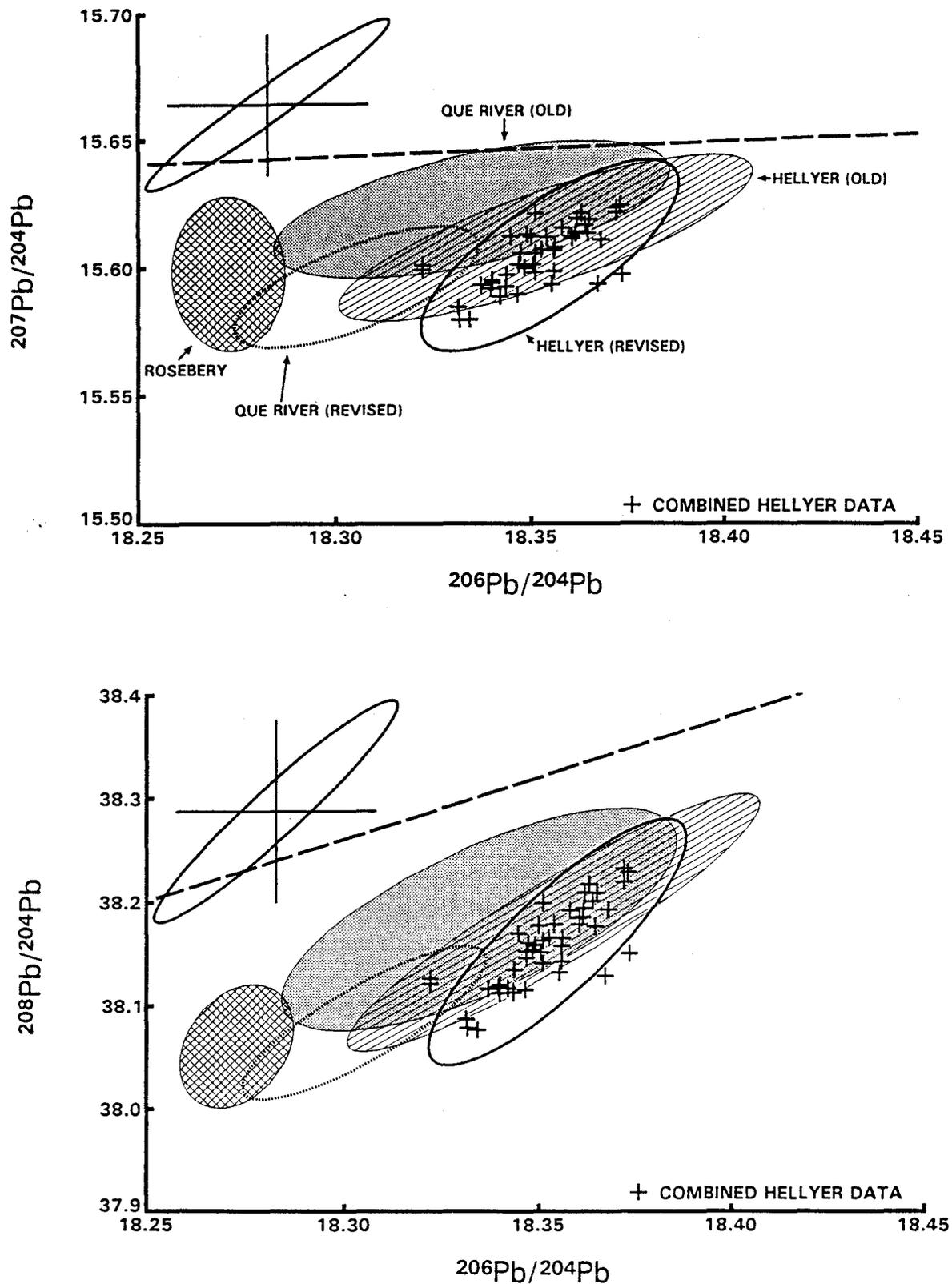
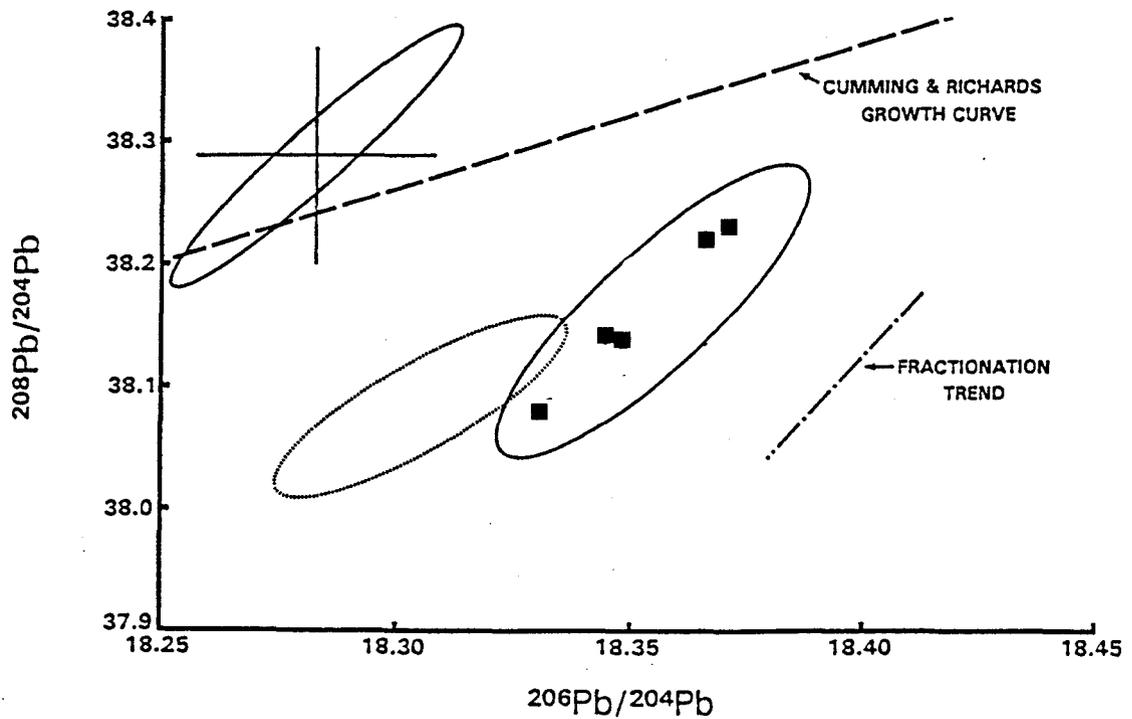
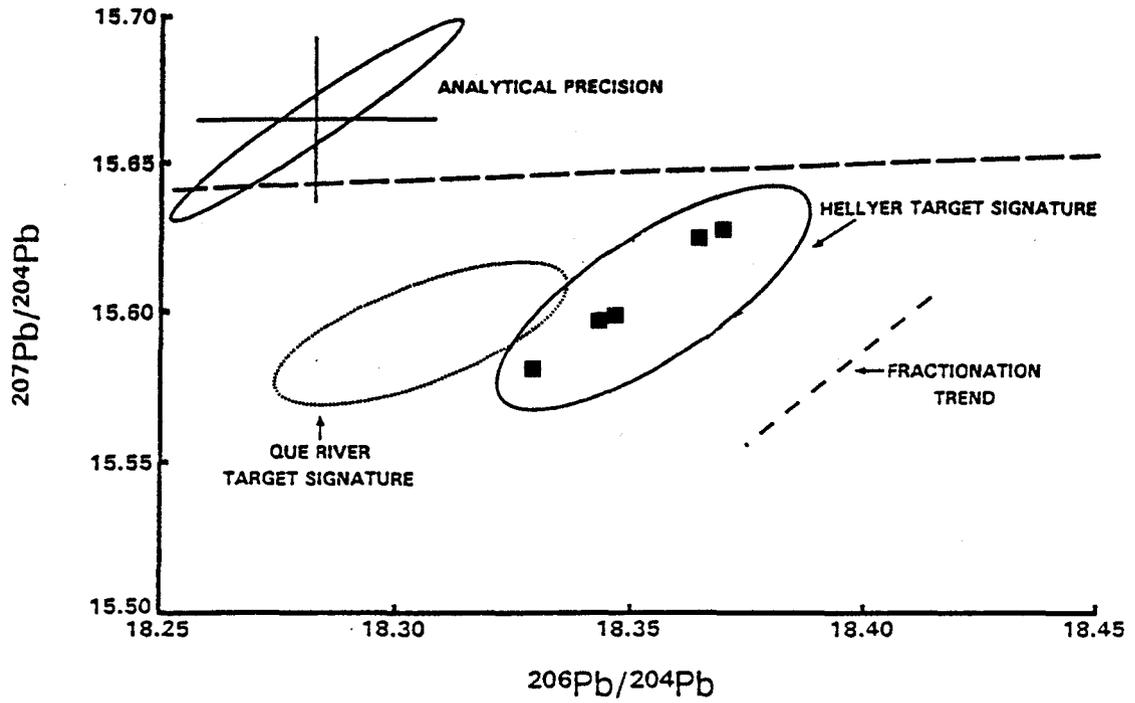


Figure 1.6

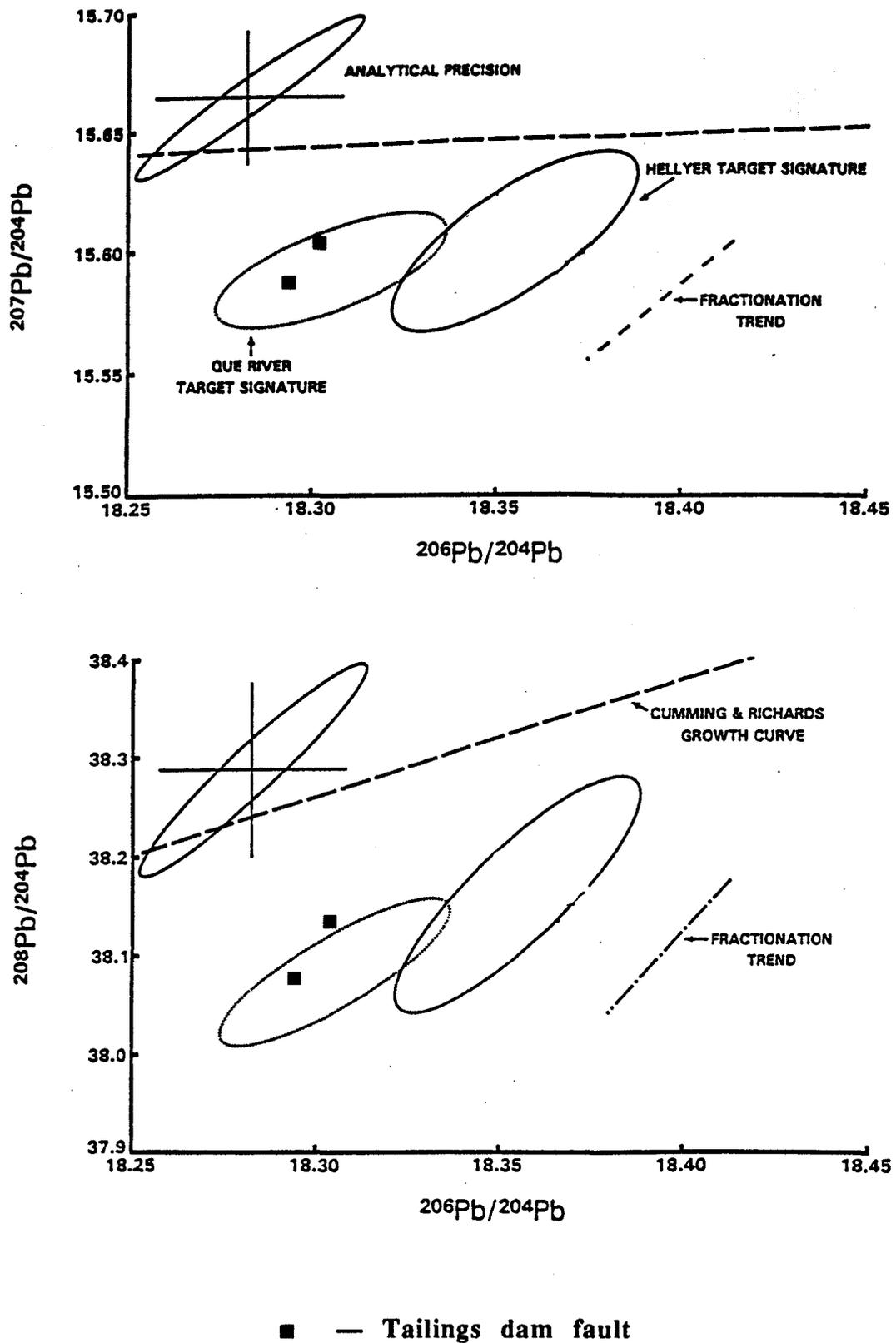
Lead isotope ratio diagrams comparing the 95% confidence ellipses (target signatures) for Hellyer (old and revised), Que River (old and revised) and Rosebery. Also shown is the complete Hellyer data set (this study and CSIRO data). The Pb evolution curve (growth curve) of Cumming and Richards (1975) is shown for reference.



■ — HL 69A BMS in PLS

Figure 1.7

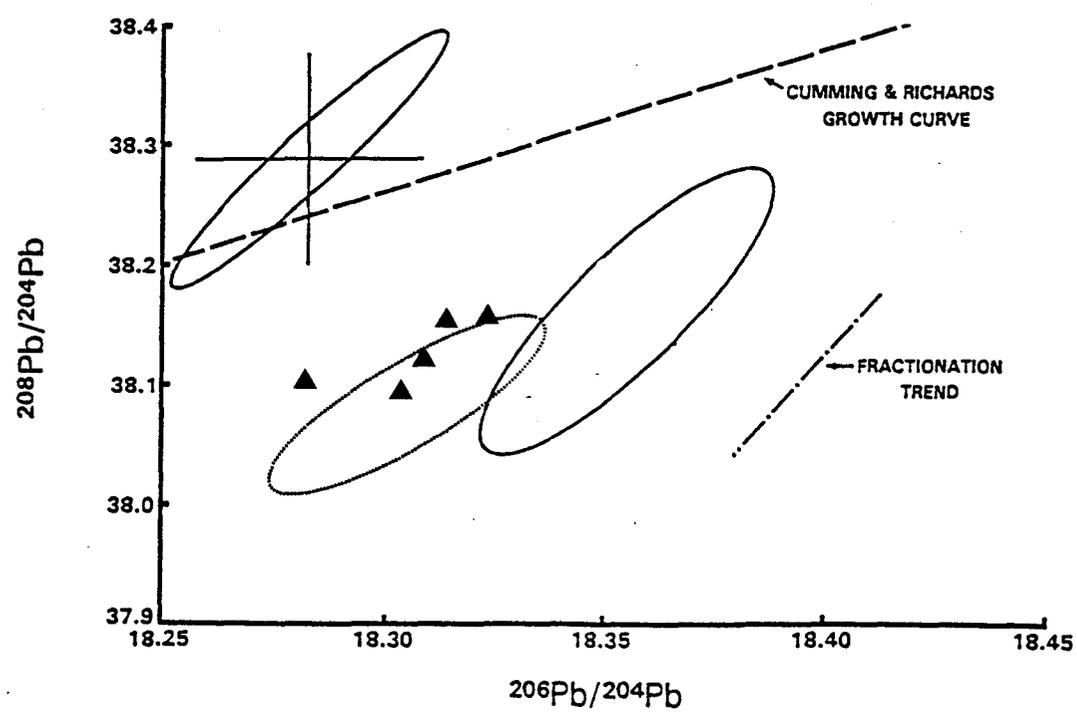
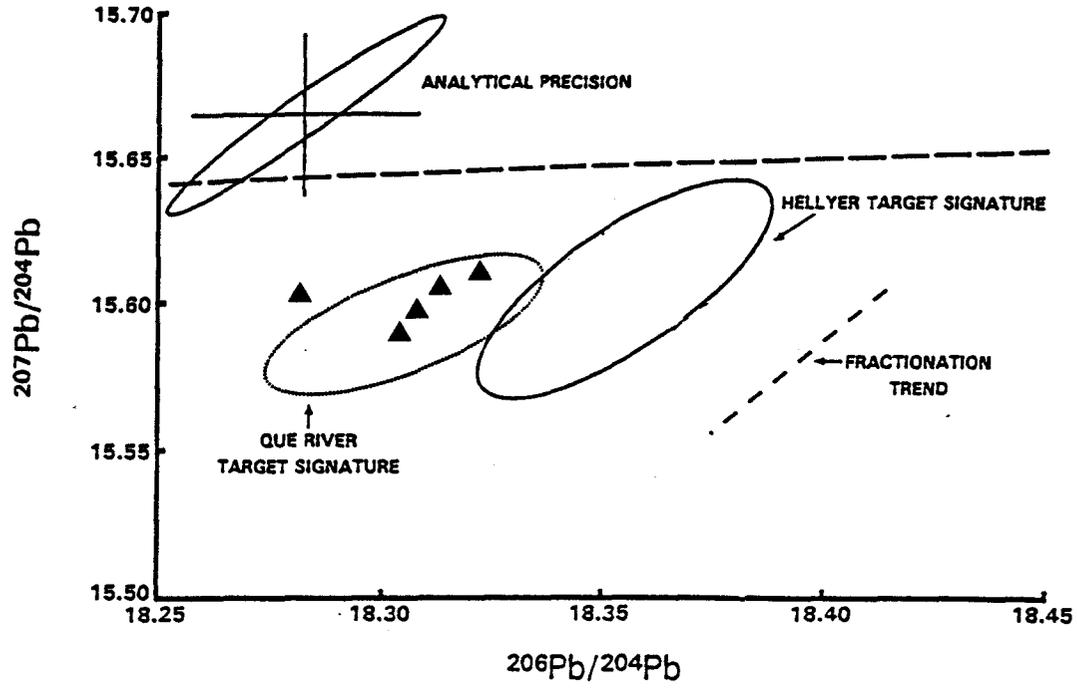
Pb isotope data for a base metal occurrence (HL 69A) in the Hellyer basalt above the Hellyer deposit on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.4. This mineralisation has the same signature as the Hellyer deposit indicating that it formed from a continuation of the Hellyer mineralising fluids passing through the hangingwall basalts.



■ — Tailings dam fault

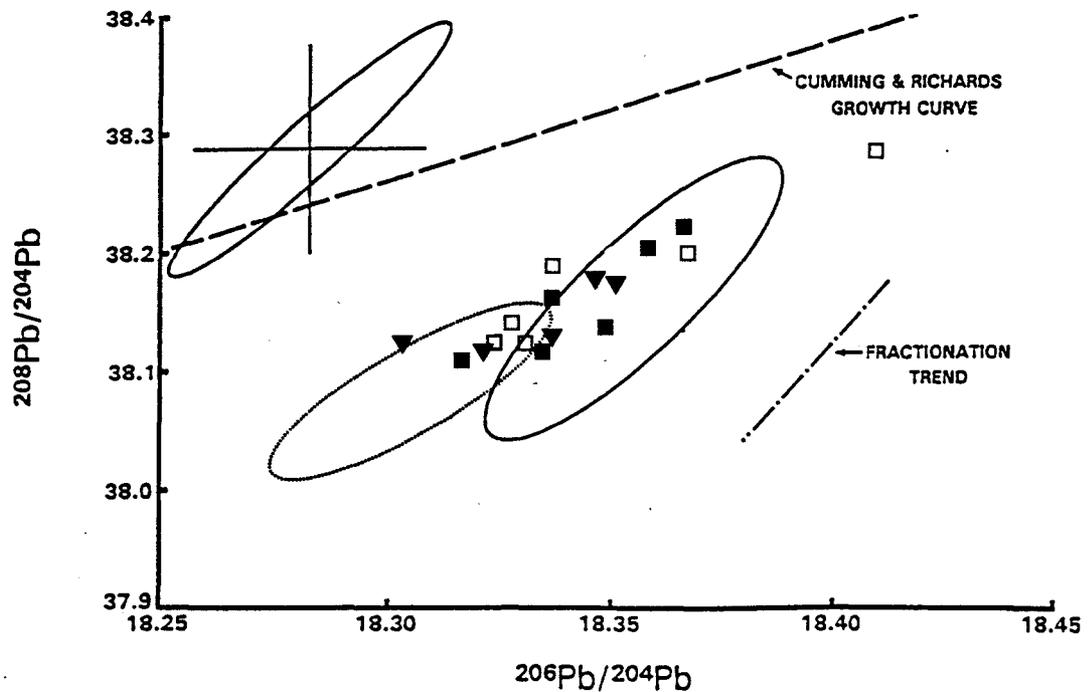
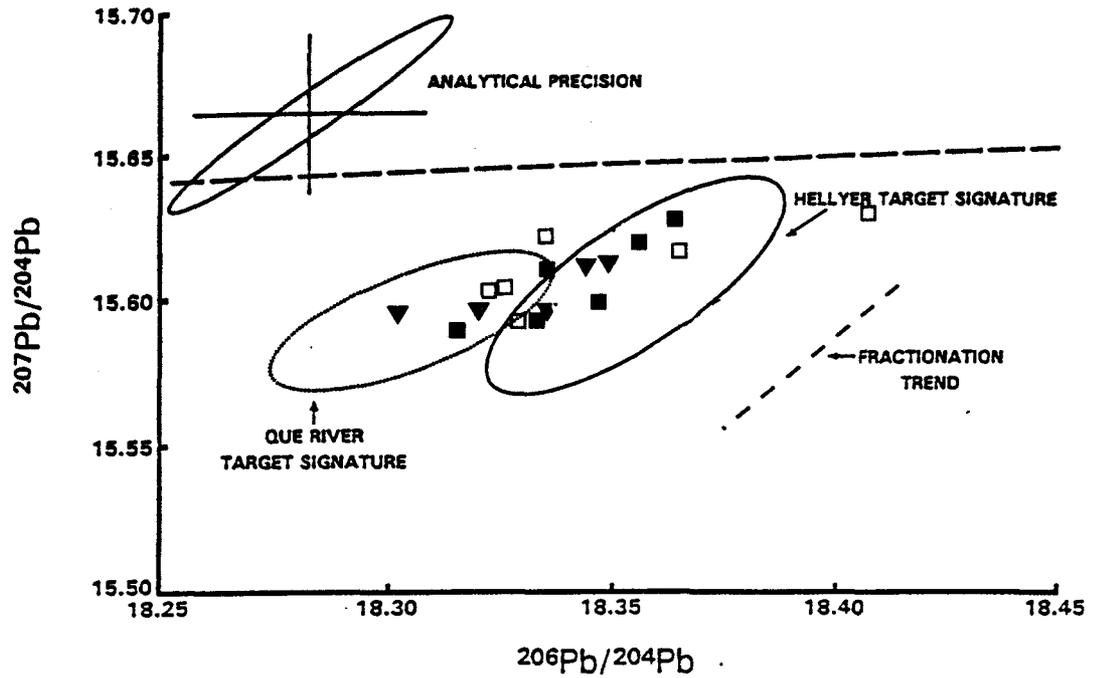
Figure 1.8

Pb isotope data for galena in a Devonian (?) fault near the Hellyer tailings dam on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.4. The galena appears to be remobilised into a Devonian structure and the Pb isotope signature may indicate that VHMS mineralisation similar to Que River may occur at depth below the tailings dam.



▲ — Sph in dolerite

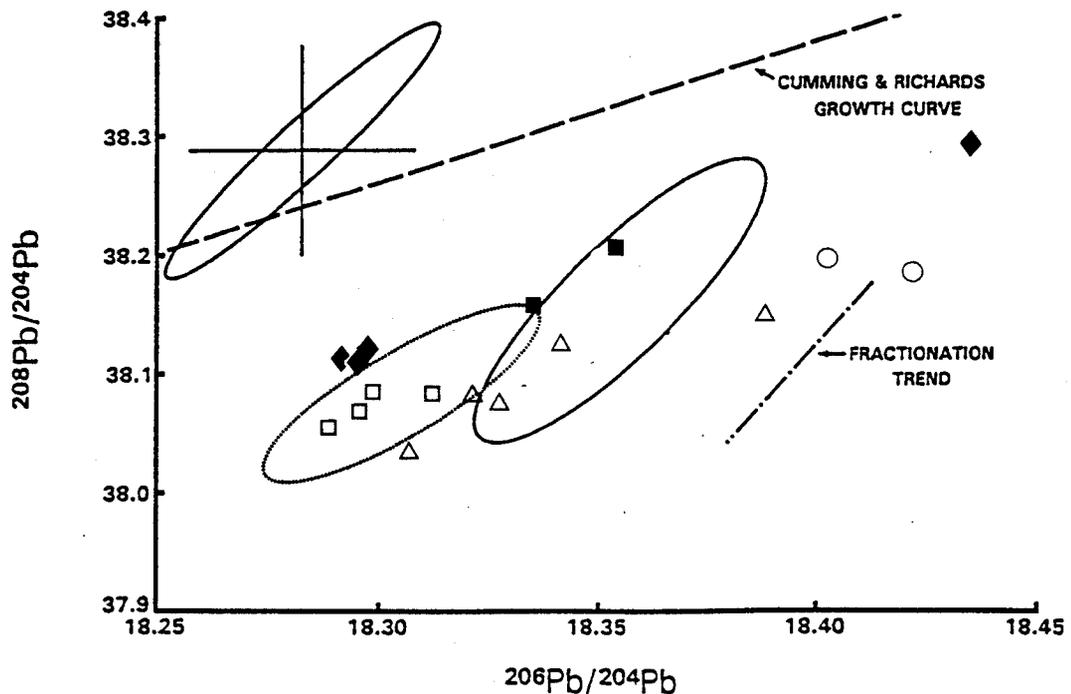
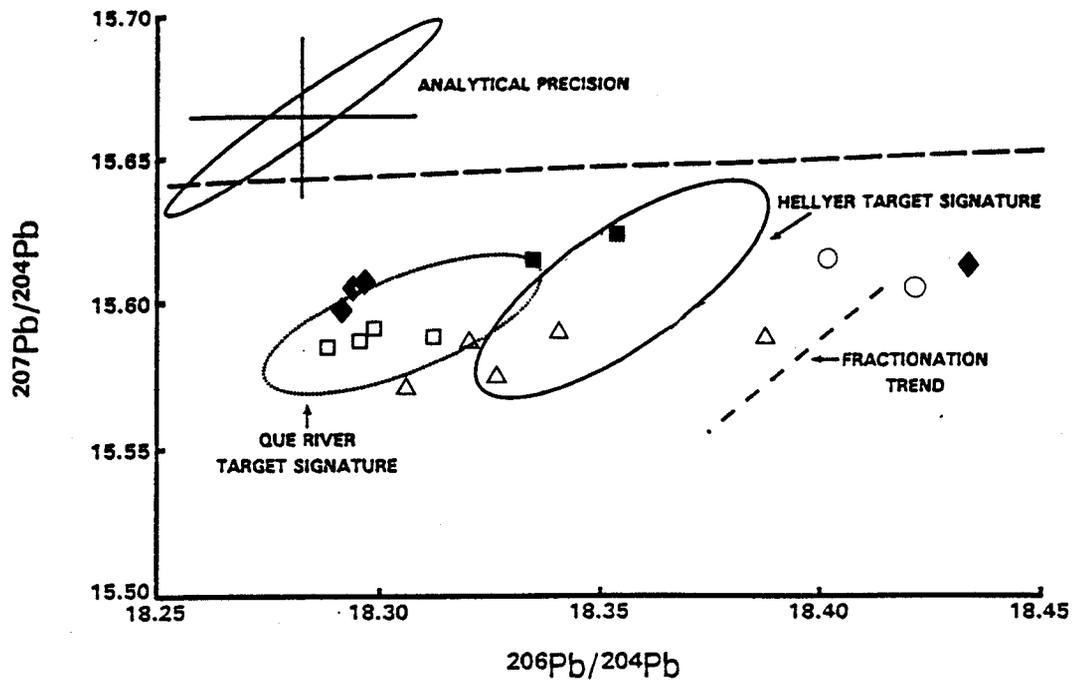
Figure 1.9
 Pb isotope data for disseminated sphalerites in a dolerite unit near Mt Charter on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.4. These data suggest that these sphalerites precipitated from fluids similar to the Que River mineralising system.



- — Switchback clasts (S. Richardson)
- — Switchback clasts (MLB 500 series)
- ▼ — MAC 8, 9 and 8900N clasts

Figure 1.10

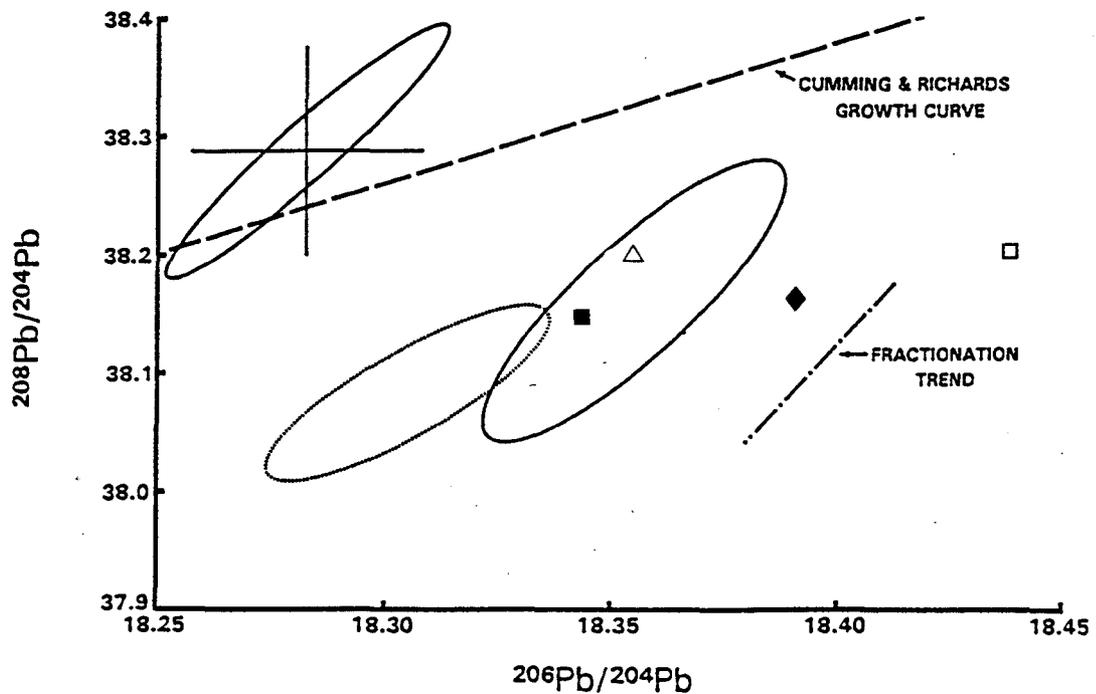
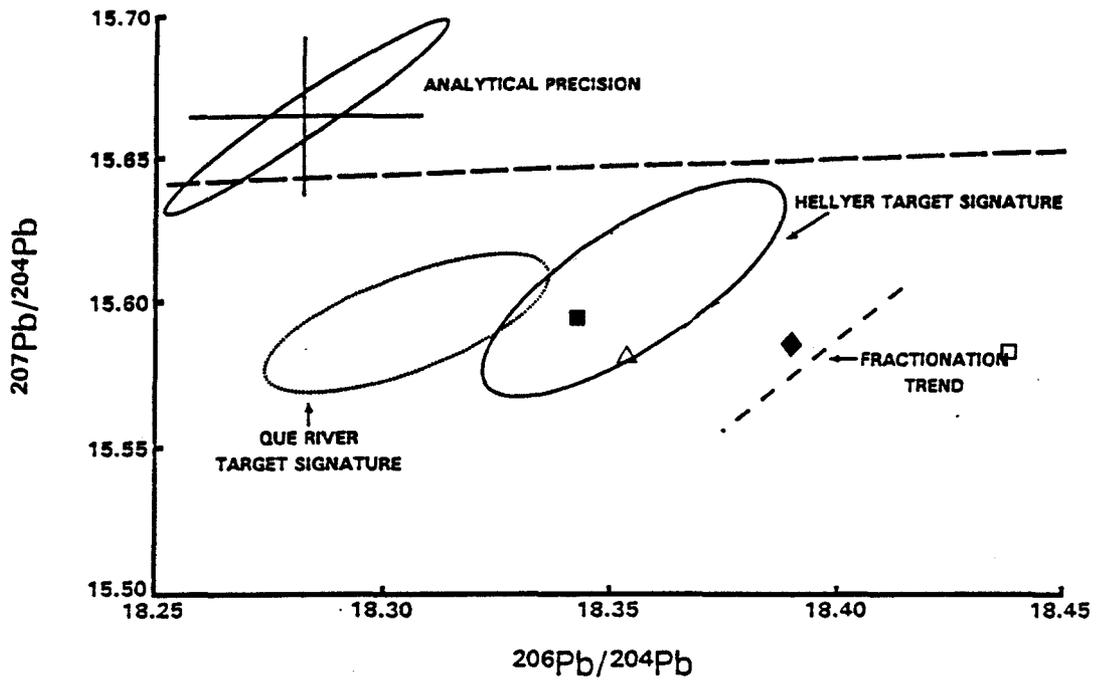
Pb isotope data for sulphide clasts at the "Switchback" and elsewhere on the Macintosh lease on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.4. The Pb isotope ratios for these high Pb-bearing clasts plot within both the Hellyer and Que River target signature ellipse, with the majority within the Hellyer ellipse.



- — Massive barite vein
- — MAC 12 Gn/Sp/Co vein in Al
- — Banded Sp in HVS
- ◆ — Gn/Co vein in Bl
- △ — C horizon soil

Figure 1.11

Pb isotope data for mineralisation and soils at Mt Charter on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.5. These data suggests that the Mt Charter mineralising system contained hydrothermal fluids with the same Pb isotopic signature as the Que River system. Abbreviations: Gn-galena, Sp-sphalerite, Co-carbonate, Al-andesite lava, HVS-hangingwall volcanoclastic sequence, Bl-basalt lava.



- — Black Harry, Py dacite
- △ — Murray's Reward, mass. Py pod
- ◆ — Henty Fault, Gn vein
- — Boundary Py/Ba vein R.L.

Figure 1.12

Pb isotope data for four mineralised prospects (Black Harry, Murray's Reward, Henty Fault and Boundary) on the Macintosh lease on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.5. Abbreviations: Py-pyrite, Mass-massive, Gn-galena, Ba-barite, RL rhyolite lava.

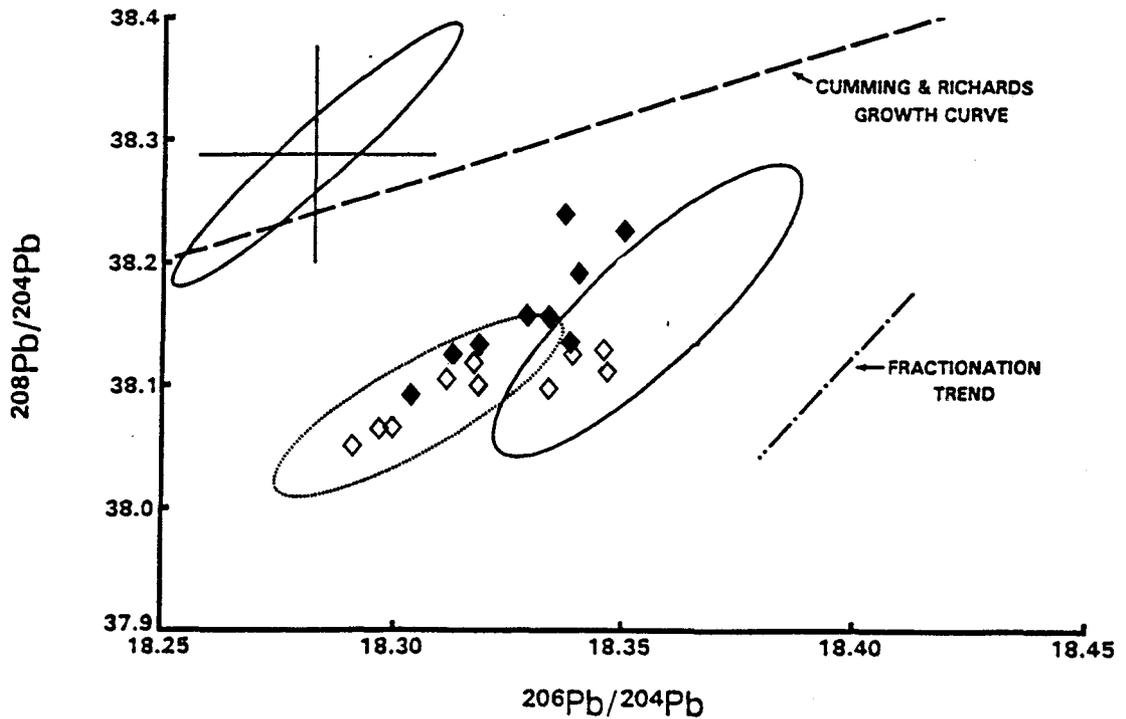
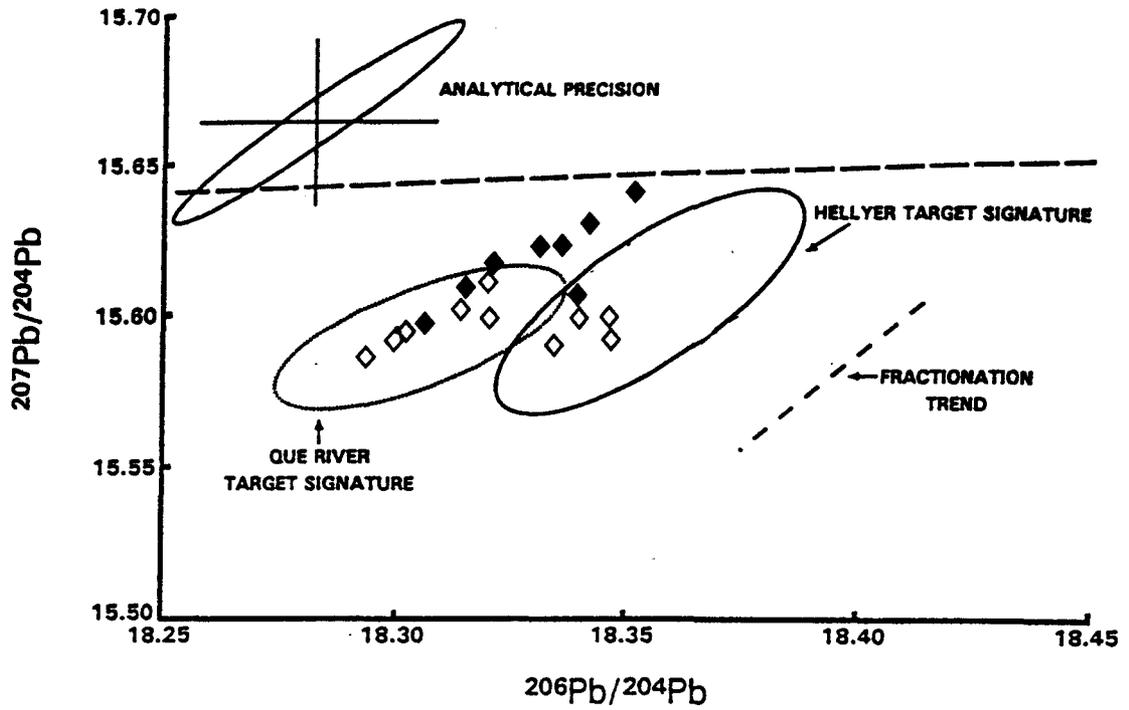
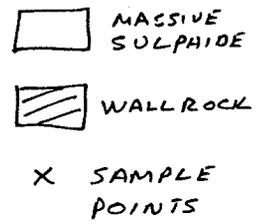
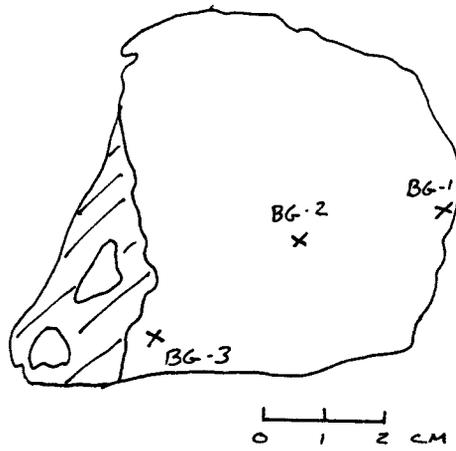


Figure 1.13

Pb isotope data for sulphide clasts from the Newton Creek Spillway on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Data from Table 1.6. Filled diamonds data from this study, open diamonds data from Carr (1992). There are two populations, one within and close to the Hellyer target ellipse and one within the Que River target ellipse. These data suggest that the Pb isotope signatures of all the clasts point strongly to a Cambrian origin for the Pb and that the two different populations indicate that the hydrothermal fluid evolved over the period of deposition in a similar manner to the evolution at Que River and Hellyer.

SAMPLE BG



SAMPLE RS

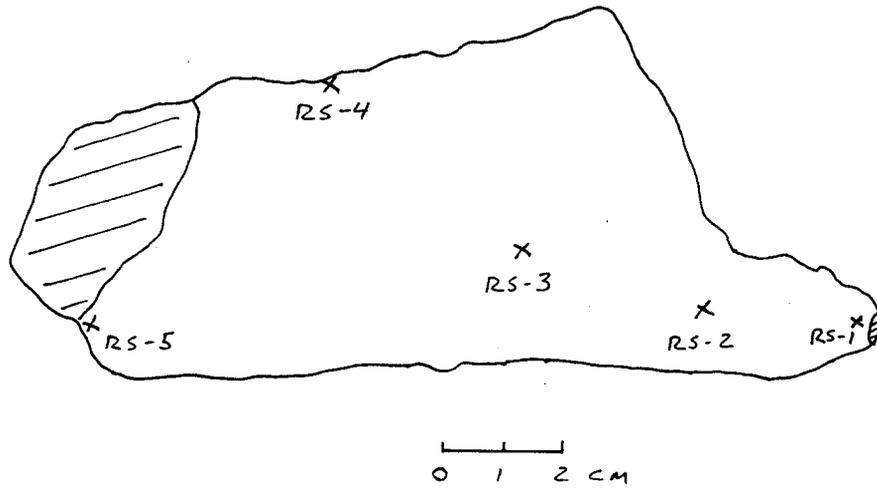
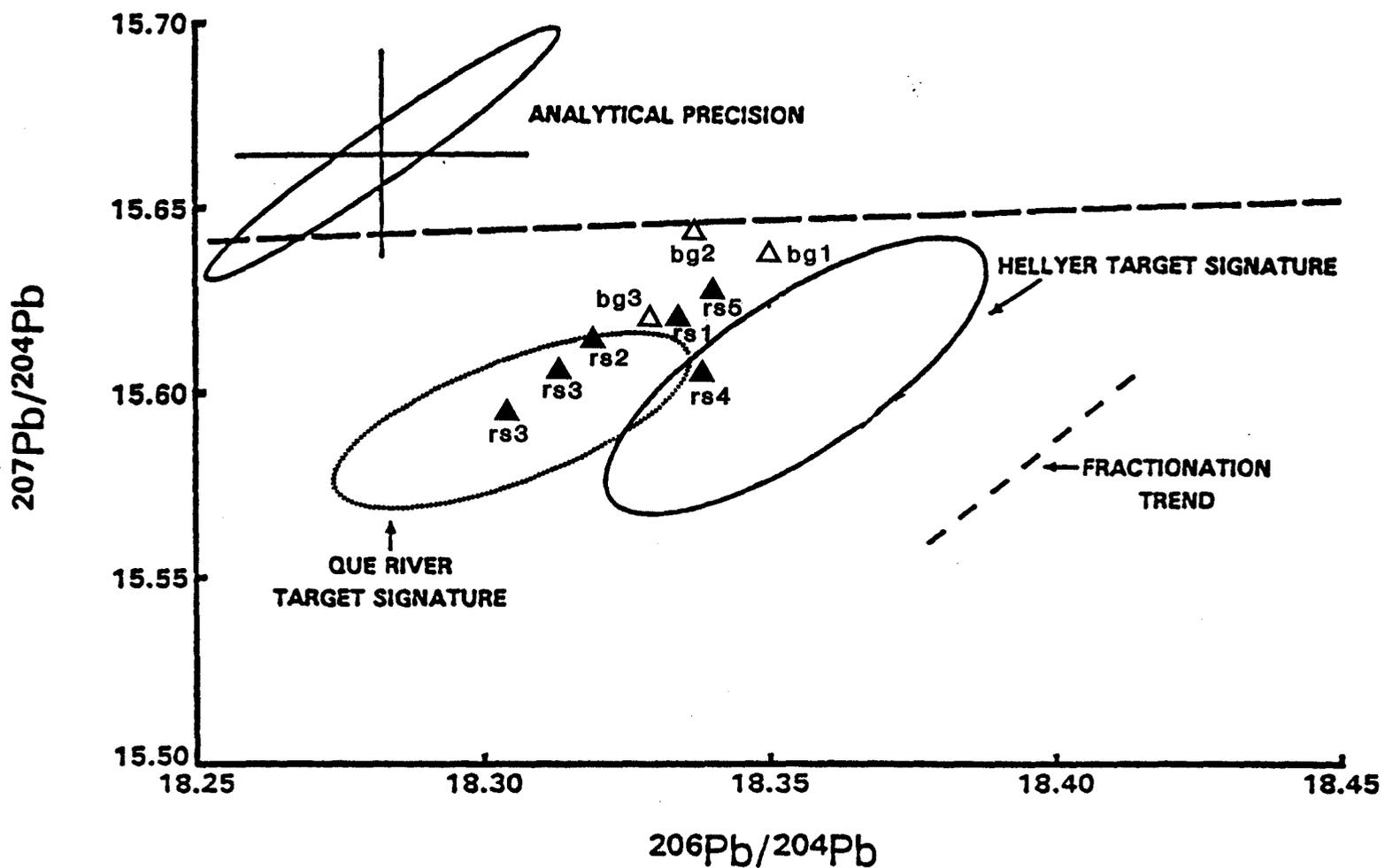


Figure 1.14
Sample locations within two sulphide clasts from the Newton Creek Spillway



- ▲ Sample RS-1
- △ Sample BG-1

Figure 1.15

Detailed Pb isotope data for core to rim traverses on sulphide clasts from the Newton Creek Spillway a $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram. Data from Table 1.6. These data indicate an apparent subtle range from lower to higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios from rim to core and indicates that the Pb isotopic composition of the fluid(s) responsible for deposition of galena in the clasts changed with time. The most reasonable explanation is that late relatively high $^{206}\text{Pb}/^{204}\text{Pb}$ fluids reacted *in situ* with the sulfide clasts.

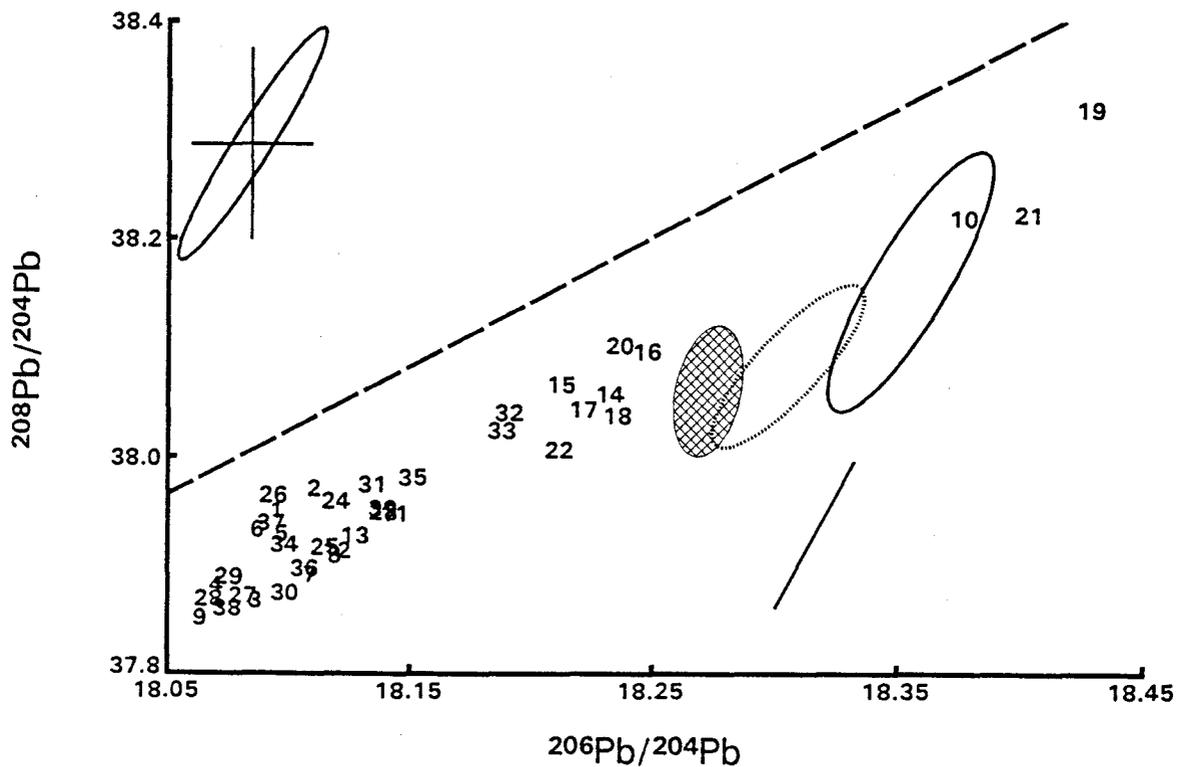
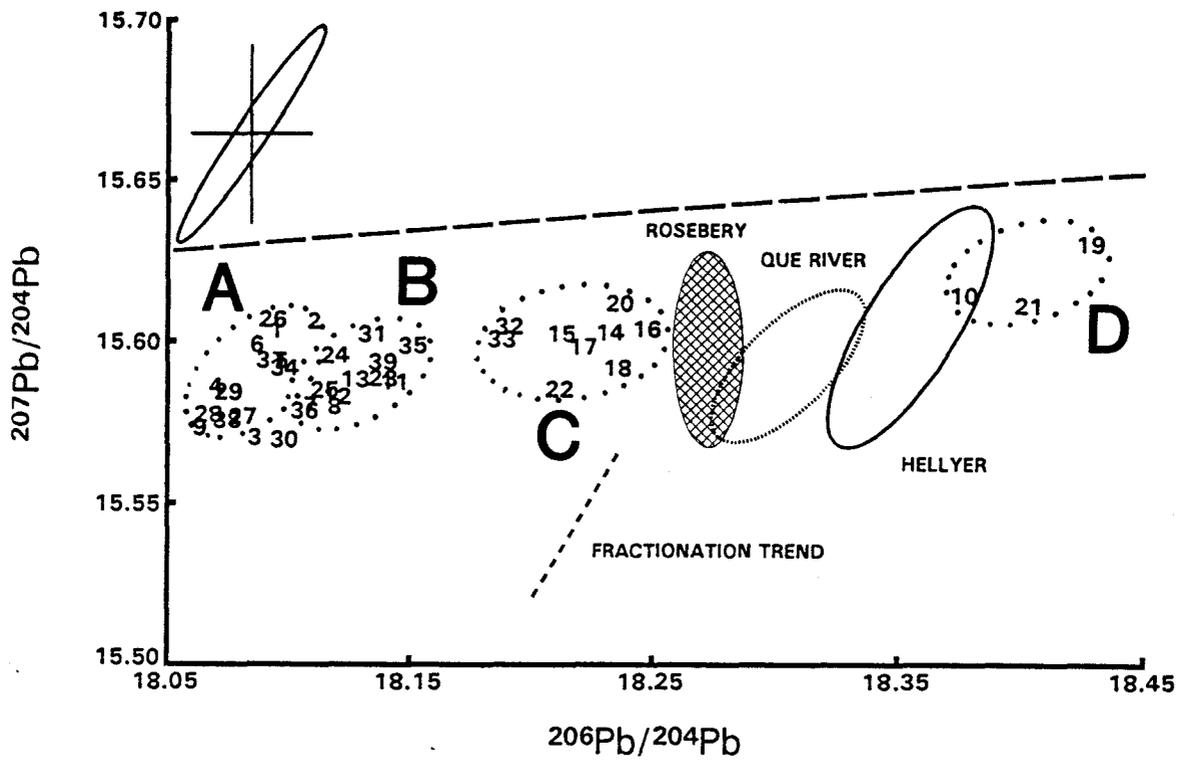


Figure 1.16

Pb isotope data for Elliott Bay on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams. Sample numbers refer to plot# in Table 1.7. Groups A and B are different populations of sulphide clasts or lenses, Group C represents disseminated and vein sulphides with alteration and Group D mineralisation is late stage veins and fracture-fill sulphides. Target signatures of the Rosebery, Que River and Hellyer massive sulphide mineralisation given for reference. dashed line is the lead evolution curve of Cumming and Richards (1975).

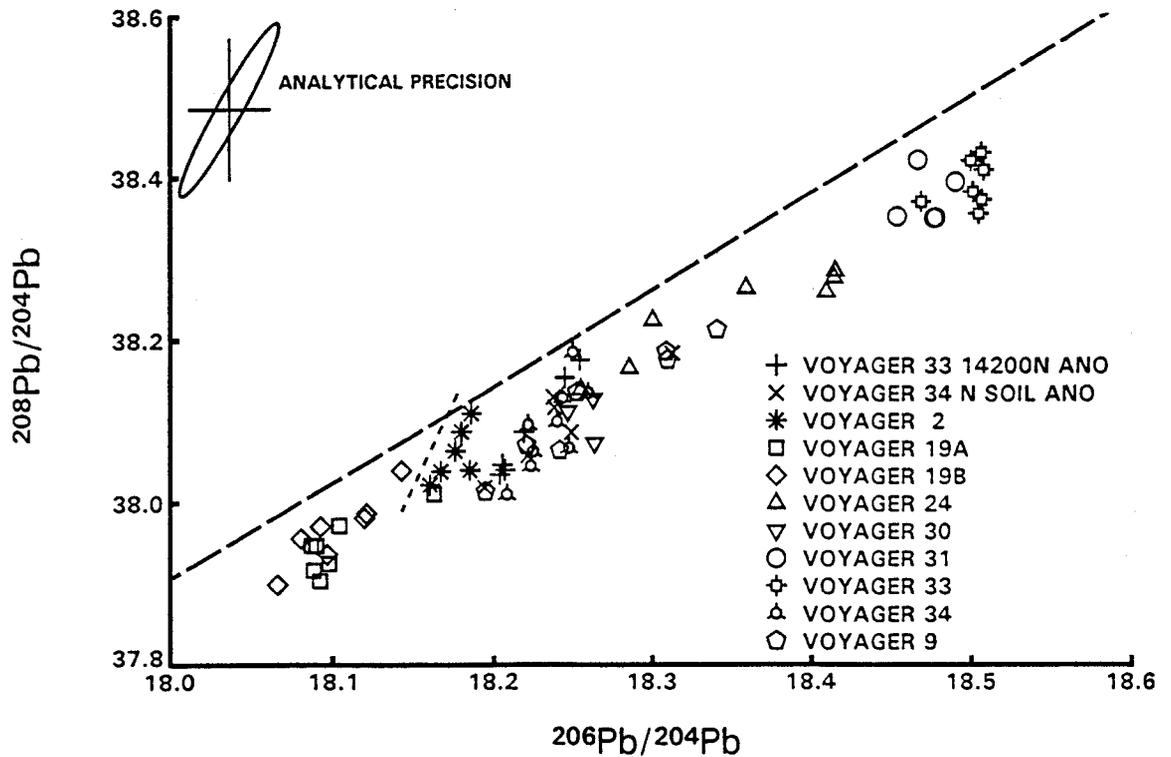
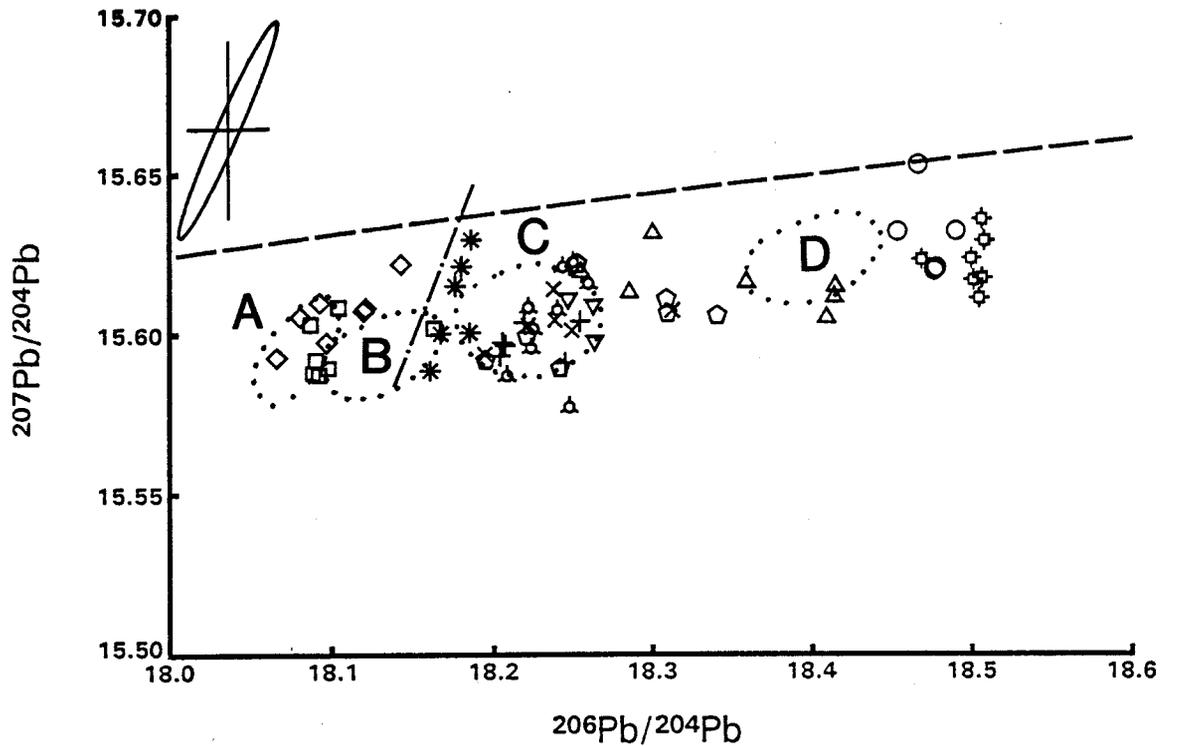


Figure 1.17

Comparison of the lead isotope data of the mineralised prospects in the Elliott Bay region (data from Gulson et al., 1987 and SIROTOPE's files) with data obtained from this study. Groups A-D same as Fig. 1.16. Short dashed line is a representative ^{204}Pb fractionation line. Long dashed line is the lead evolution (Growth) curve of Cumming and Richards (1975).

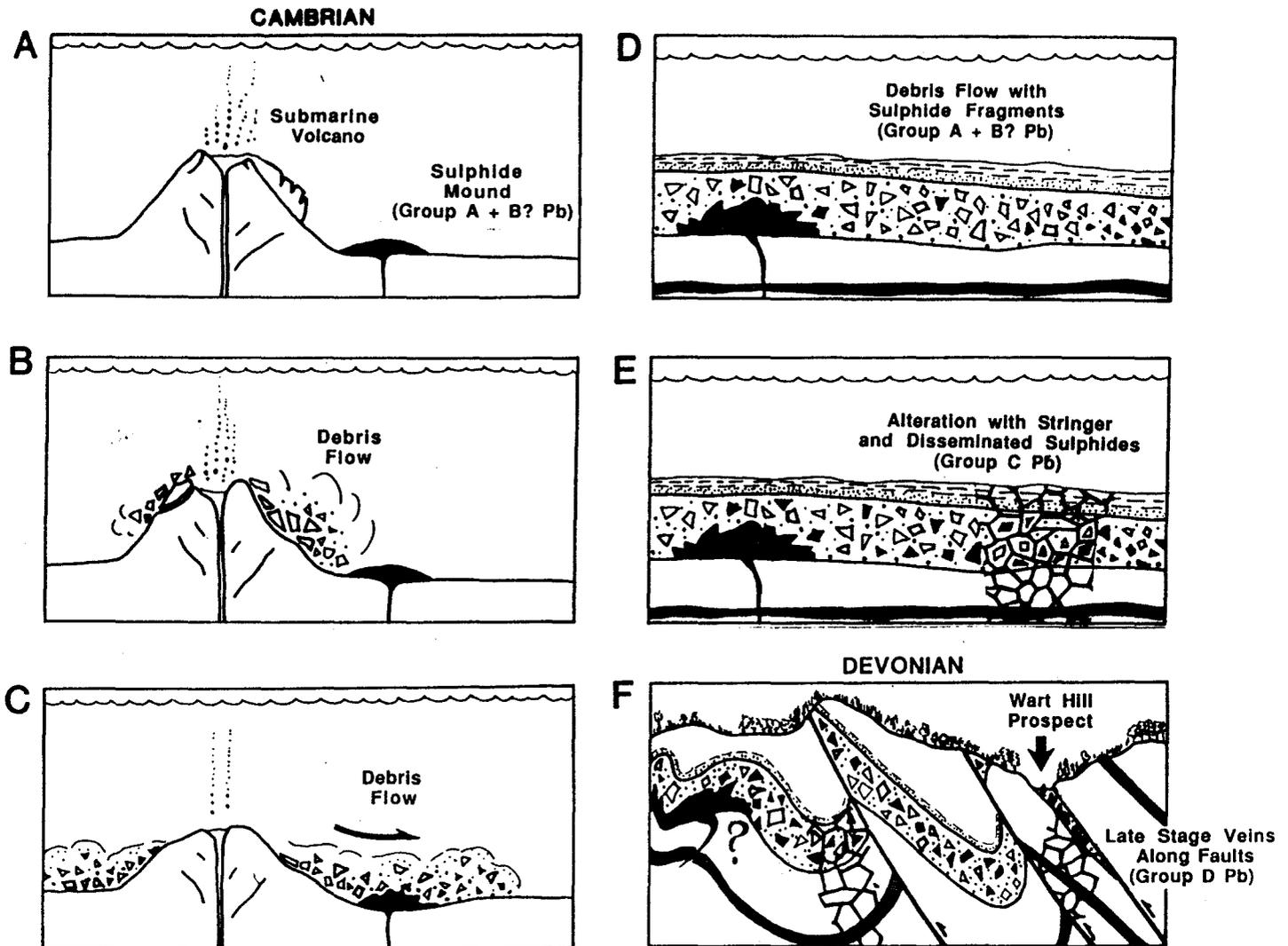


Figure 1.18

Working model for types of Elliott Bay mineralisation and differing Pb isotope signatures. A. In the Cambrian a volcanic-hosted massive sulphide deposit (Pb Groups A and B), of unknown size formed on the seafloor somewhere in the vicinity of Wart Hill. B. and C. Subaqueous debris flows incorporated fragments of this mineralisation and deposited them at the present day site of Wart Hill. D. These fragments became one of the clast types in the debris flow deposits. E. Shortly after the deposition of the debris flows a separate generation of hydrothermal fluids passed through these rocks causing alteration (sericite, quartz, chlorite, minor carbonate) and precipitation of disseminated and stringer sulphide mineralisation (Pb Group C). F. During, or shortly after, the Devonian deformation another generation of hydrothermal fluids passed through the rocks causing minor alteration and sulphide mineralisation along faults and fractures (Pb Group D).

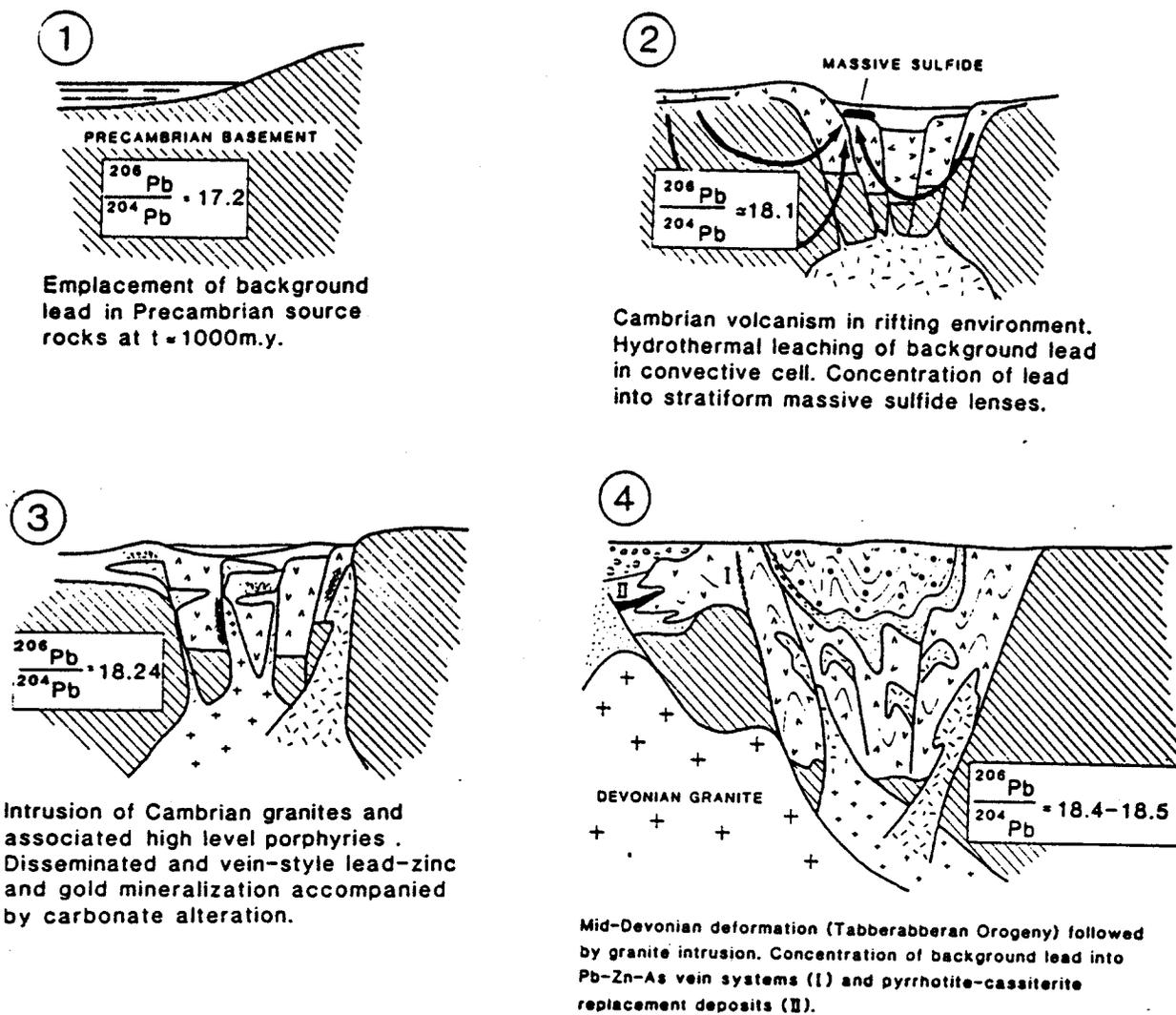


Figure 1.19

Gulson et al.'s (1987) model explaining the evolution of lead isotope signatures for the mineralisation and host rock at Elliott Bay.

Table 1.1

Stringer zone Pb isotope data.

ORIGINAL Pb ISOTOPE DATA - analysed at Dartmouth College, USA (1990)

Sample	Location	Mineralogy	Vein Stage	206/204	207/204	208/204	Pb (ppm)	U (ppm)
HL 306-64	52.5m	Pyrite	2A	18.370	15.609	38.197	1150	<0.05
HL 306-67	57.5m	Galena	2B	18.360	15.608	38.174	—	—
HL 306-112	180.0m	Pyrite	2A	18.486	15.610	38.381	—	—
HL 306-125	223.9m	Galena	2B	18.379	15.628	38.240	—	—
HL 306-128	242.1m	Pyrite	2A	18.392	15.637	38.268	995	0.2
HL 306-136	270m	Chalcopyrite	2B	18.382	15.627	38.240	1%	<0.05
HL 306-151	300m	Chalcopyrite	2B	18.348	15.582	38.141	—	—
HL 306-176	377.4m	Chalcopyrite	2B	18.406	15.662	38.336	—	—
HL 306-176	377.4m	Pyrite	2A	18.391	15.626	38.268	—	—
HL 306-191	441.0m	Pyrite	2A	18.404	15.656	38.279	—	—
HL 306-194	482.4m	Pyrite	2A	18.413	15.609	38.230	—	—
HL 093-17	44.9m	Galena	2B	18.398	15.633	38.270	—	—
HL 93-25	64.0m	Pyrite	2B	18.411	15.666	38.366	5750	2.60
HL 6-1	301.7m	Pyrite	2A SEZ	18.495	15.620	38.289	1700	0.22
HL 6-8	394.4m	Galena	2B	18.402	15.650	38.331	—	—
HL 6-3	449.7m	Pyrite	2A SEZ	18.429	15.604	38.265	120	0.27
HL 29-1	224.5m	Pyrite	2C	18.418	15.688	38.413	5950	3.5
HL 22-1	465.3m	Pyrite	2A	18.440	15.634	38.283	—	—
A/HL-1	DECLINE 350 L	Pyrite	2A SEZ	18.467	15.621	38.306	91	0.13
A/HL-24	85-86 W XCUT	Galena	2A	18.372	15.621	38.221	—	—
A/HL-26	85-86 W XCUT	Galena	2B	18.392	15.647	38.304	—	—
A/HL-51C	77-81 S DRIVE	Galena	2B	18.367	15.618	38.207	—	—

RE-ANALYSIS - analysed at CSIRO (1991 and 1992)

A/HL 1	as above	Pyrite	2A (SEZ)	18.415	15.592	38.196	178	—
A/HL 1	as above	Pyrite	2A (SEZ)	18.446	15.622	38.292	99	—
A/HL -55	85-74 S DRIVE	Pyrite	2A (SEZ)	18.377	15.596	38.172	519	—
HL93-25	as above	Pyrite	2A	18.345	15.586	38.102	4720	—
HL93-25	as above	Pyrite	2A	18.359	15.601	38.145	4720	—
HL 6-1	as above	Pyrite	2A (SEZ)	18.303	15.584	38.066	4680	—
HL 6-3	as above	Pyrite	2A (SEZ)	18.462	15.595	38.242	156	—
HL 6-8	as above	Galena	2B	18.380	15.617	38.215	> 1%	—
HL 6-8	as above	Galena	2B	18.362	15.593	38.143	> 1%	—
HL 6-8	as above	Galena	2B	18.385	15.622	38.236	> 1%	—
HL 6-8	as above	Galena	2B	18.364	15.593	38.157	> 1%	—
HL 6-9	398m	Pyrite	2A (SEZ)	18.365	15.615	38.193	588	—
HL 6	466m	Pyrite	2A (SEZ)	18.487	15.637	38.365	63	—
HL 15	361.8m	Pyrite	2A (SEZ)	18.387	15.617	38.244	804	—
HL 306-64	as above	Pyrite	2A	18.332	15.574	38.067	1610	—
HL 306-67	as above	Galena	2B	18.342	15.585	38.101	> 1%	—
HL 306-67	as above	Galena	2B	18.348	15.586	38.113	> 1%	—
HL 306-67	as above	Galena	2B	18.342	15.587	38.104	> 1%	—

Table 1.2
Hellyer Pb isotope data

Plot Sample #	Location	Section	Mineral	Min type	Ore type	206/204	207/204	208/204	
1	H-1	HL 547 97.7m	10250N	Gn	MaVn	FWD	18.355	15.594	38.132
2	H-2	HL 656 102.4m	10370N	Sp,Gn,Py	MaDs	GSP	18.351	15.621	38.199
3	H-3	HL 656 117.5m	10370N	Gn,Sp	MaSsRx	HWE	18.344	15.593	38.112
4	H-4	HL 656 136.3m	10370N	Cp,Py	MaSsRx	MPY	18.368	15.634	38.230
5	H-6	HL 493 170.3m	10490N	Sp,Gn,Py	MaRxVn	GSP/BMS	18.373	15.597	38.150
6	H-7	HL 493 186.0m	10490N	Gn	BnFr	HWE	18.365	15.614	38.177
7	H-8	HL 493 208.3m	10490N	Gn,Sp	MaBn	HWE	18.356	15.607	38.158
8	H-9	HL 654 99.0m	10490N	Gn,Sp	Bx	HWE	18.334	15.580	38.076
9	H-9R	HL 654 99.0m	10490N	Gn,Sp	Bx	HWE	18.353	15.607	38.165
10	H-11	HL 452 65.9m	10610N	Sp,Gn	BxCmVn	HWE	18.347	15.601	38.146
11	H-12	HL 452 38.5m	10610N	Sp,Gn,Py	MaBn	HWE	18.351	15.598	38.141
12	H-13	HL 443 85.7m	10610N	Sp,Gn	MaSsBn	BA/GSP	18.362	15.614	38.194
13	H-14	HL 443 72.6m	10610N	Sp,Gn	RxBx	HWE	18.340	15.592	38.118
14	H-15	HL 455 54.0m	10610N	Gn,Sp	BnSs	HWE	18.361	15.612	38.178
15	H-16	HL 332 25.1m	10710N	Gn,Sp	MaBn	HWE	18.331	15.585	38.087
16	H-17	HL 334 50.3m	10710N	Sp,Gn	FrCmRx	GSP	18.331	15.580	38.078
17	H-18	HL 328 11.3m	10710N	Gn	MaBnRx	HWE	18.361	15.612	38.185
18	H-19	HL 328 55.3m	10710N	Sp,Gn,Py	MaBnFr	FWD	18.365	15.619	38.209
19	H-20	HL 224 36.1m	10710N	Py	FrRx	HWE	18.345	15.612	38.170
20	H-21	HL 94 62.8m	10850N	Py,Cp	VnDsMa	MPY	18.347	15.590	38.115
21	H-22	84-83 crosscut	10850N	Py,Cp	RxVn	MPY	18.337	15.593	38.116
22	H-23	HL 94 100.5m	10850N	Sp,Gn,Py	BnRx	HWE	18.347	15.601	38.153
23	H-24	HL 94 121.3m	10850N	Gn,Sp	BnFr	HWE	18.379	15.636	38.258
24	H-25	HL 91 59.9m	10850N	Sp,Gn	BnMaRx	BA	18.367	15.594	38.128
25	H-26	HL 91 43.9m	10850N	Sp,Gn	BnMa	HWE	18.362	15.619	38.209
26	H-27	HL 189 4.0m	10910E	Gn,Sp	FrBn	FWD	18.350	15.601	38.152
27	H-28	HL 189 46.7m	10910N	Gn	MaSsBn	HWE	18.356	15.599	38.142
28	H-30	HL 196 83.8m	10910N	Gn,Sp	MaBnRx	HWE	18.347	15.606	38.161
39	H-31	HL 196 54.5m	10910N	Gn,Sp	MaBn	HWE	18.356	15.608	38.165
30	H-32	HL 127 124.0m	11030N	Gn,Sp	BnFrRx	HWE	18.358	15.616	38.192
31	H-33	HL 284 122.0m	11030N	Gn	Bn	HWE	18.361	15.613	38.185
32	H-33R	HL 284 122.0m	11030N	Gn	Bn	HWE	18.344	15.597	38.135
33	H-33R	HL 284 122.0m	11030N	Gn	Bn	HWE	18.340	15.594	38.112

Table 1.3
Que River Pb isotope data

Sample	Drill Hole	Depth	Ore type	Mineral	206/204	207/204	208/204	Pb (ppm)
QR 502987	QR 310	42.1m	BMS	galena	18.304	15.606	38.129	>10,000
QR 502983	QR 405	40.5 m	BMS	galena	18.317	15.601	38.117	>10,000
QR 502951	QR 417	25 m	BMS	galena	18.304	15.604	38.123	>10,000
QR 502962	QR 311	36.8 m	BMS	galena	18.319	15.599	38.124	>10,000
QR 502977	QR 428	32.5 m	BMS	galena	18.362	15.614	38.210	18400
QR 502701	QR 783	83 m	BMS	galena	18.325	15.600	38.125	>10,000
QR 502958B	QR 311	40 m	STZ	galena	18.321	15.617	38.155	>10,000
QR 502911A	QR 278	79 m	STZ	pyrite	18.319	15.598	38.121	22400
QR 502903C	QR 276	76.3 m	STZ	galena	18.362	15.595	38.137	>10,000
QR 87-502-701	QR 740	89.4 m	STZ-Au	galena	18.336	15.590	38.107	>10,000
QR 87-502-704	QR 801	20 m	STZ-Au	galena	18.307	15.606	38.133	>10,000
QR 503968	QR 1060A	892.2 m	STZ-deep	pyrite	18.332	15.601	38.133	3140
QR 503969	QR 1060A	994.2 m	STZ-deep	pyrite	18.392	15.605	38.211	833
QR 503970	QR 1060A	1077.1 m	STZ-deep	pyrite	18.358	15.612	38.193	613
QR 503970	QR 1060A	1077.1 m	STZ-deep	pyrite	18.380	15.637	38.279	625
QR 503971	QR 1060A	1234.0 m	STZ-deep	pyrite	18.484	15.620	38.294	420
QR 503971	QR 1060A	1234.0 m	STZ-deep	pyrite	18.526	15.611	38.354	1070
QR 503975	QR 1169	455.6 m	STZ-deep	pyrite	18.722	15.634	38.582	1840
QR 503979	QR 1169	711.2 m	STZ-deep	pyrite	18.358	15.596	38.157	1980

Table 1.4
Mackintosh lease Pb isotope data

Sample	Location	Mineral	206/204	207/204	208/204	Pb (ppm)
HL 69A	402m	galena	18.329	15.581	38.077	>10,000
HL 69A	402m	galena	18.364	15.625	38.221	>10,000
HL 69A	402m	galena	18.369	15.628	38.231	>10,000
HL 69A	401.5 m	galena	18.343	15.597	38.141	>10,000
HL 69A	401.5 m	galena	18.347	15.599	38.138	>10,000
495 level	75-84 SD	chalcopyrite	18.244	15.618	37.510	229
495 level	75-84 SD	chalcopyrite	20.995	15.788	38.698	37
Tailings dam	fault	galena	18.294	15.588	38.078	>10,000
Tailings dam	fault	galena	18.302	15.605	38.126	>10,000
MAC 27	274 m	sphalerite	18.281	15.603	38.104	1710
MC 14	165.9 m	sphalerite	18.303	15.590	38.136	103
MAC 29	195 m	galena	18.321	15.611	38.158	>10,000
MAC 29	196.3 m	sulfides	18.312	15.606	38.155	4970
MAC 29	196.3 m	sulfides	18.307	15.598	38.123	4970
SB 1	switchback clast	sulfide	18.535	15.621	38.160	4500
SB 2	switchback clast	sulfide	18.335	15.610	38.163	36700
SB 2	switchback clast	sulfide	18.333	15.593	38.118	7880
SB 3	switchback clast	sulfide	18.315	15.590	38.109	1780
SB 4	switchback clast	sulfide	18.347	15.599	38.138	3530
SB 5	switchback clast	sulfide	18.356	15.620	38.205	14800
SB 6	switchback clast	sulfide	18.364	15.628	38.223	5520
MAC 9	38.1 m	galena	18.349	15.613	38.174	>10,000
MAC 8	34.7 m	galena	18.302	15.596	38.095	>10,000
MAC 1	225.6 m	galena	18.320	15.597	38.117	>10,000
MLB 1	8900N boulder	galena	18.344	15.612	38.179	>10,000
MLB 1	8900N boulder	galena	18.335	15.596	38.132	>10,000
MLB 500965	switchback clast	galena	18.322	15.604	38.124	>10,000
MLB 500966	switchback clast	galena	18.326	15.605	38.140	>10,000
MLB 500978	switchback clast	galena	18.329	15.594	38.123	>10,000
MLB 500970	switchback clast	sulfide	18.407	15.635	38.288	1070
MLB 500977	switchback clast	sulfide	18.335	15.622	38.190	640
MLB 500981	switchback clast	sulfide	18.365	15.617	38.200	725

Table 1.5

Mt Charter and Mackintosh lease Pb isotope data

Prospect	Sample no.	DDH (m)	Depth	Grid N	Grid E	Sample type	Description	206/204	207/204	208/204	Pb (ppm)
Charter	355179	MC12	140.3:			whole rock	Gn+Sp+Carb vn in Al	18.289	15.584	38.054	>10,000
Charter	355180	MC12	140.3:			whole rock	Gn+Sp+Carb vn in Al	18.312	15.587	38.083	>10,000
Charter	355181	MC12	163			whole rock	Gn+Sp+Carb vn in Al	18.299	15.590	38.085	>10,000
Charter	355182	MC12	199.3			whole rock	Gn+Sp+Carb vn in Al	18.296	15.586	38.068	>10,000
Charter	355183			5401	3673	c horizon	A-DI	18.306	15.571	38.036	2400
Charter	355184			5399	3669	c horizon	A-DI	18.386	15.588	38.152	495
Charter	355185			5399	3612	c horizon	?Al	18.326	15.575	38.077	1045
Charter	355186			5406	3594	c horizon	?Al	18.340	15.590	38.127	810
Charter	355187			5406	3589	c horizon	?Al	18.320	15.587	38.083	1600
Charter	S30			3900	4060?	whole rock	Gn+Carb vn in Bl	18.292	15.596	38.113	>10,000
Charter	S31			3900	4060?	whole rock	Gn+Carb vn in Bl	18.296	15.605	38.125	>10,000
Charter	S32			3900	4060?	whole rock	Gn+Carb vn in Bl	18.295	15.604	38.111	>10,000
Charter	S33			4100	4150	whole rock	Gn+Carb vn in Bl	18.431	15.612	38.295	>10,000
Charter	S34			4625	4290	whole rock	mas Ba vn	18.353	15.622	38.207	-
Charter	S35			4645	4280	whole rock	mas Ba vn	18.334	15.613	38.158	-
Charter	S36	MC9	159.5			whole rock	bnd Sp in Hvs	18.419	15.604	38.186	200
Charter	S37	MC9	159.6			whole rock	bnd Sp in Hvs	18.400	15.614	38.198	860
Murrays Rd	271221			13535	6825	whole rock	mass Py pod	18.354	15.581	38.197	145
Boundary	271234			2990	2820	whole rock	Py-Ba vn R.I.	18.436	15.581	38.197	225
Henty Fault	427426			-0.155	6080	mineral	Gn vn.	18.389	15.585	38.159	>10,000
Black Harry	427814			12680	1880	whole rock	Py dacite	18.343	15.594	38.144	525

Source: All data from Carr and Dean (1985), SIROTOPE Report to Aberfoyle Resources Ltd.

Table 1.6
Newton Creek sulphide clasts Pb isotope data

Sample	Location	Mineral	206/204	207/204	208/204	Pb (ppm)
BG-1	Newton Ck	galena	18.350	15.639	38.227	>10,000
BG-2	Newton Ck	galena	18.337	15.645	38.243	>10,000
BG-3	Newton Ck	galena	18.329	15.622	38.158	>10,000
RS-1	Newton Ck	galena	18.334	15.622	38.156	>10,000
RS-2	Newton Ck	galena	18.319	15.616	38.135	>10,000
RS-3	Newton Ck	galena	18.304	15.597	38.091	>10,000
RS-3	Newton Ck	galena	18.313	15.608	38.124	>10,000
RS-4	Newton Ck	galena	18.338	15.607	38.134	>10,000
RS-5	Newton Ck	galena	18.340	15.629	38.194	>10,000
Carr (1992) data						
Clast 1	Newton Creek	galena	18.339	15.601	38.126	>10,000
Clast 1R	Newton Creek	galena	18.334	15.592	38.097	>10,000
Clast 2	Newton Creek	galena	18.318	15.610	38.118	>10,000
Clast 3	Newton Creek	galena	18.319	15.559	38.100	>10,000
Clast 4	Newton Creek	galena	18.312	15.601	38.104	>10,000
Clast 5	Newton Creek	galena	18.347	15.595	38.110	>10,000
Clast 5R	Newton Creek	galena	18.346	15.601	38.127	>10,000
Clast 6	Newton Creek	galena	18.300	15.594	38.064	>10,000
Clast 6 (562358)	Newton Creek	galena	18.298	15.561	38.063	>10,000
Clast 7	Newton Creek	galena	18.291	15.585	38.049	>10,000
Clast 7R	Newton Creek	galena	18.297	15.590	38.063	>10,000

Table 1.7
Elliott Bay Pb isotope data

Plot Sample	Location	Mineralisation Type	Mineral	206/204	207/204	208/204	GROUP	
1	EB 1000	WH 2 33.m	SUS CLAST	Gn,Sp	18.095	15.604	37.951	A
2	EB 1001	WH 2 35.9m	DISSEM IN CHL ALT	Py,Sp,Gn	18.111	15.606	37.972	A
3	EB 1002	WH 2 44.2m	MASS SUS	Sp,Gn	18.086	15.571	37.869	A
4	EB 1003	WH 2 47.3m	STRINGER IN SIL ALT	Sp,Gn	18.070	15.586	37.883	A
5	EB 1004	WH 2 48.9m	MASS SUS	Sp,Gn	18.097	15.594	37.930	A
6	EB 1005	WH 4 49.8m	SUS CLASTS	Sp,Gn	18.083	15.592	37.907	A
7	EB 1006	WH 4 53.4m	SUS CLASTS	Sp,Gn	18.109	15.581	37.893	B
8	EB 1007	WH 4 54.0m	MASS SUS	Sp,Gn	18.119	15.580	37.910	A
9	EB 1008	WH 4 84.8m	MASS SUS	Sp,Gn	18.063	15.574	37.852	A
10	EB 1009	WH 5 279.1m	LATE VEIN	Gn	18.377	15.615	38.219	D
11	EB 1010	WH 6 48.0m	SUS CLAST IN SIL ALT	Gn,Sp	18.143	15.588	37.948	B
12	EB 1011	WH 6 50.0m	SUS CLAST IN SIL/SER ALT	Gn,Sp	18.121	15.583	37.914	B
13	EB 1011re	WH 6 50.0m	SUS CLAST IN SIL/SER ALT	Gn,Sp	18.128	15.589	37.928	B
14	EB 1012	WH 6 58.5m	SUS CLAST	Sp,Gn	18.233	15.603	38.058	C
15	EB 1013	WH 7 95.1m	SUS IN ALT	Sp,Gn	18.212	15.603	38.067	C
16	EB 1014	WH 9 114.8m	SUS IN SER ALT	Gn	18.248	15.604	38.097	C
17	EB 1015	WH 8 109.5m	STRINGER IN SER/CARB ALT	Sp,Gn	18.221	15.599	38.044	C
18	EB 1016	WH 8 148.7m	STRINGER IN SER/CARB ALT	Sp,Gn,Py	18.236	15.592	38.039	C
19	EB 1017	WH 8 261.0m	DISSEM SUS IN SIL ALT	Gn	18.428	15.630	38.319	D
20	EB 1018	WH 10 76.4m	STRINGER	Sp,Gn,Py	18.236	15.612	38.102	C
21	EB 1019	WH 10 81.6m	DISSEM SUS IN SER ALT	Py,Gn,Sp	18.402	15.611	38.222	D
22	EB 1020	WH 10 170.2m	STRINGER IN SIL ALT	Sp, Gn	18.211	15.586	38.007	C
23	EB 1021	WH 10 187.5m	CLAST?	Gn,Sp	18.139	15.589	37.950	B
24	EB 1021re	WH 10 187.5m	CLAST?	Gn,Sp	18.120	15.596	37.960	B
25	EB 1022	WH 10 189.3m	SUS CLAST	Gn,Sp	18.115	15.585	37.918	B
26	EB 72079	WH 2 45.5m	SUS MATRIX	Gn,Sp,Py	18.118	15.627	38.027	A
27	EB 72080	WH 8 185.0m	MASS SUS	Gn,Sp	18.081	15.577	37.873	A
28	EB 72085	WH 4 47.0m	SUS MATRIX	Gn,Sp,Py	18.067	15.578	37.870	A
29	EB 72086	13310N 10060E	MASS SUS	Gn,Sp	18.075	15.585	37.891	A
30	EB 72087	13040N 10060E	MASS SUS	Gn,Sp	18.098	15.570	37.876	B
31	EB 72089	WH 4 54.0m	MASS SUS	Gn,Sp	18.134	15.603	37.975	B
32	EB 72096	13080N 10020E	MASS SUS	Gn,Sp	18.191	15.605	38.041	C
33	EB 72096r	13080N 10020E	MASS SUS	Gn,Sp	18.188	15.601	38.024	C
34	EB 72094	WH 2 35.5m	SUS MATRIX	Py,Sp,Gn	18.099	15.592	37.920	A
35	EB 72111	WH 10 189.3m	MASS SUS	Sp,Gn	18.151	15.599	37.982	B
36	EB 72112	13040N 10060E	MASS SUS	Gn,Sp	18.107	15.579	37.898	B
37	EB 72113	13040N 10040E	SUS BRXX	Py,Sp,Gn	18.093	15.595	37.940	A
38	EB 72121	13310N 10085E	MASS SUS	Sp,Gn	18.075	15.576	37.862	A
39	EB 72075	WH 4 48.1m	SUS MATRIX	Sp,Gn	18.139	15.594	37.953	B

1992 Exploration

			Pb (ppm)				
CSN 565551	near coast	SOIL	814	18.252	15.584	38.050	C
CSN 565209	near coast	SOIL	1290	18.177	15.583	37.992	C
565531	on coast	SULPHIDE	> 1 %	18.215	15.590	38.014	C
565531	on coast	SULPHIDE	> 1 %	18.228	15.611	38.075	C
565532?	on coast	SULPHIDE	> 1 %	18.223	15.596	38.037	C
565530	on coast	SULPHIDE	> 1 %	18.171	15.582	37.969	B-C?
565576	on coast	SULPHIDE	> 1 %	18.181	15.606	38.040	B-C?

Abbreviations: MASS=massive, SUS=sulphide, BRXX=breccia, DISSEM=disseminated, ALT=alteration, Gn=galena, Sp=sphalerite, Py=pyrite, NS=no sample, re=repeat sample

Part 2

Source Rock Study – Relationship of Hydrothermal and Magmatic Pb Isotope Signatures in the Mount Read Volcanics

Studies by Gulson and Porritt (1987) and Gulson et al. (1987), and subsequent reports to Aberfoyle Resources by SIROTOPE (e.g. Carr, 1988; Carr and Dean, 1989) have shown that there is a significant range in Cambrian Pb isotopic signatures within the Mt Read Volcanic Belt (Fig. 1.3) for which there may be regional, as well as stratigraphic, control. These differences suggest different source rocks for the Pb (and other metals) during the evolution of the hydrothermal systems.

Previous studies in massive sulphide districts have shown the significance of varying underlying stratigraphic units on the isotopic composition of Pb in the deposits. For example, Fehn et al. (1983) determined that a major part of the Pb in the Kuroko deposits of the Hokuroku district, Japan, was derived from the host volcanics, but also that a significant contribution was from the underlying Cenozoic formations and most likely also from the Paleozoic basement. LeHuray et al. (1987) and Mills et al. (1987) documented basement controls on the Pb isotopic composition of the sediment-hosted Zn-Pb mineralisation in central Ireland.

To properly understand the Pb isotope systematics of the Elliott Bay and the Hellyer-Que River VHMS systems, and the range of Cambrian Pb isotope signatures throughout the Mt Read Volcanic Belt, the connection must be made with the initial Pb isotope ratios of the potential source rocks (Pb isotope ratios of the rocks at the time of ore formation). The present-day Pb isotope ratios of the potential source rocks are probably not initial ratios because of the addition of radiogenic Pb since the Cambrian. However, initial ratios can be determined from unaltered, magmatic components of the source rocks that have low U/Pb

ratios, such as potassium feldspar and clinopyroxene.

Although the Pb isotope signatures of the various styles of mineralisation throughout western Tasmania are documented (Gulson and Porritt, 1987), very little Pb isotope data exist for the host rocks. The only whole-rock Pb isotope data for the Que-Hellyer volcanics are from footwall and hangingwall lithologies surrounding the Que River deposit (Gulson and Porritt, 1981; Gulson and Porritt, 1982; Gulson et al., 1990). No whole-rock Pb isotope data is available from the Central Volcanic Complex or any of the underlying Cambrian lithologies. Whole-rock Pb isotope data for some of the Precambrian units are reported in Gulson et al. (1990).

The limited Pb isotope data for the Precambrian basement rocks, metamorphosed sedimentary rocks (siltstones, quartzites, carbonates) and mafic intrusives and lavas led Gulson et al. (1990) to suggest that all the values are probably radiogenic, i.e. ^{206}Pb has been added in situ by radioactive decay of ^{238}U since the time of formation, and that they have been subjected to younger metamorphic and possibly hydrothermal events. However, these data led Gulson et al. (1987; 1990) to suggest that Pb in both the Mount Read Volcanics and the associated VHMS mineralisation was derived from a Precambrian basement source and that the variations observed between the VHMS deposits arise from the complexity and variability of the source rocks.

In addition to determining the likely sources of metal in ores from the Mt Read Volcanic Belt, Pb isotope data can be used to develop a model to explain the anomalous nature of the Pb isotopic composition of the ores, as compared to other VHMS belts in the

Tasman Orogen. Such a model is critical in evaluating the Pb isotopic systematics of the known ore occurrences and in predicting the Pb isotope signatures of undiscovered mineralisation in different parts and stratigraphic levels of the Belt. Lead isotope signatures of exploration prospects, in combination with a potential Pb isotope stratigraphy of the source rocks, could be used to discriminate prospects in the exploration for future mineral resources.

Sampling

Samples from all Cambrian and older lithologies throughout the west coast of Tasmania were analysed in this portion of the study. Unaltered samples were obtained from the Central Volcanic Complex, Que-Hellyer volcanics, Cambrian granitic and porphyry intrusions, mafic-ultramafic complexes, Crimson Creek Formation and the Precambrian metamorphic basement rocks of the Tyennan Block. Each sample has been described petrographically and has major and minor element whole-rock analysis (Stolz and Large, 1988; 1992). Host rocks for the Elliott Bay mineralisation were collected from core stored in Zeehan and also potentially from collections made by Aberfoyle geologists working at Elliott Bay. In addition Tony Crawford provided pyroxene samples from unaltered Hellyer basalt and Paul Kitto provided samples of the Devonian Pine Hill and Heemskirk granites.

2.1 Precambrian Mafics

These data are presented in Table 2.1 and in Figure 2.1. The results were reported by Gulson 1990 and are re-interpreted in this report. All samples contain low-Pb and thus are not considered as representing initial ratios. The data plot along linear arrays on both diagrams. The slope of the regression onto the data in the $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram suggests a Proterozoic age, however there is a very low precision, principally because of the wide range of $^{207}\text{Pb}/^{204}\text{Pb}$ ratios for samples at the low

$^{206}\text{Pb}/^{204}\text{Pb}$ end of the array. These data can be divided into two end members (Figure 2.1);

- samples with high $^{207}\text{Pb}/^{204}\text{Pb}$ ratios (termed high μ group, "H" in Table 2.1) and,
- samples with low $^{207}\text{Pb}/^{204}\text{Pb}$ ratios (termed low μ group, "L" in Table 2.1).

The *low μ group* plots close to the mantle curve with $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios similar to modern average MORB (PREMA, see Zindler and Hart, 1986) (Figure 2.2) and with distinctly lower $^{207}\text{Pb}/^{204}\text{Pb}$ ratios than the MRV massive sulfide mineralisation. The *high μ group* has $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios similar to the massive sulfide mineralization (Figure 2.2) The regression through this data give a more precise apparent age of 1070 ± 100 Ma. On the $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ plots the low μ data have significantly higher $^{208}\text{Pb}/^{204}\text{Pb}$ ratios than the crustal growth curve and the MRV massive sulfide mineralization (Figure 2.2). In contrast, the high μ samples again are similar to the mineralization.

Because the data do not represent initial ratios, we can place no great significance on the similarity of the *high μ group* and the Cambrian ore signatures. We can broadly model the range of possible Pb isotope ratios of these rocks as they would have been in the Cambrian. The results indicate that the $^{207}\text{Pb}/^{204}\text{Pb}$ ratios would have been higher, but would still overlap the massive sulfide fields. Thus these rocks could possibly have supplied Pb to the hydrothermal fluids during the Cambrian. The *low μ group* however, are most unlikely to have been a source of Pb to these fluids.

2.2 Precambrian Sediments

Again, no initial ratios were obtained from these low-Pb samples. The results plot on arrays with the least radiogenic data on the $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram similar to the Cambrian

hydrothermal signatures (Table 2.2, Figure 2.2 and 2.3). However, on the $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram the least radiogenic data all have significantly higher $^{208}\text{Pb}/^{204}\text{Pb}$ ratios than the Cambrian hydrothermal signatures. This relative difference would also have been apparent in the Cambrian and so it is concluded that these metasedimentary rocks *are unlikely to have been major sources of Pb to the hydrothermal fluids* responsible for mineralization in either the Que-Rosebery-Hellyer-Mt Lyell belt or the Elliott Bay region.

2.3 Crimson Creek Formation

Two Crimson Creek Formation samples were analysed using sequential leaching techniques and displayed a range of isotopic compositions (Table 2.3, Figure 2.4). We are uncertain whether these samples represent initial ratios, however the sample with the lowest $^{206}\text{Pb}/^{204}\text{Pb}$ ratio is similar to the Cambrian massive sulfide mineralization except that it has a higher $^{208}\text{Pb}/^{204}\text{Pb}$ ratio. This difference is significant and suggests that these Crimson Creek Formation rocks could only have been a source of Pb to the mineralization if such Pb had been mixed with another source with $^{208}\text{Pb}/^{204}\text{Pb}$ ratios lower than the mineralization. No such source has been identified in this study and thus we believe the Crimson Creek Formation is unlikely to have been a significant source of metals to the Cambrian hydrothermal event.

2.4 Cambrian Granites

Lead isotope results for the Cambrian intrusive rocks are given in Table 2.4. The results are plotted in Figure 2.5. The data lie on linear arrays on both $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagrams with the lowest $^{206}\text{Pb}/^{204}\text{Pb}$ data clustering within or close to the Que River target ellipses. The high- $^{206}\text{Pb}/^{204}\text{Pb}$ data represent radiogenic addition since the Cambrian. Some of the samples which plot within the Que River ellipse contain up to 600 ppm Pb (7528001, 7528002) which indicates

they have been hydrothermally altered and thus the data do not represent magmatic initial ratios. However, other samples have normal magmatic values of Pb (10 - 50 ppm). The close isotopic similarity of these Cambrian intrusive and mineralization data strongly suggest that the *average Pb in the magma sources of the Cambrian intrusives had the same Pb isotopic composition as the Pb in the hydrothermal fluids responsible for deposition of the massive sulfide mineralization.*

2.5 Central Volcanic Complex

Low-Pb data from these rocks (Table 2.5) plot on a linear array on the $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram which indicate an apparent isochron age of 400 ± 100 Ma (Figure 2.6). This young age most probably results from partial metamorphic resetting. Of more significance is the fact that the lowest $^{206}\text{Pb}/^{204}\text{Pb}$ sample is close to the Cambrian mineralization target ellipses. The data distribution is very similar to those of the Cambrian intrusive rocks and the Que-Hellyer Volcanics (discussed below) which together lie on a linear regression representing an apparent age of 420 ± 50 Ma, again suggesting metamorphic resetting (Figure 2.7). This overall similarity and the fact that all data appear to project back through an initial ratio indistinguishable from the Cambrian massive sulfide ellipses suggests that the Central Volcanic Complex rocks probably had initial Pb isotope ratios similar to the Cambrian intrusive rocks and/or the Que-Hellyer Volcanics and thus *probably represented a source of metals for the mineralization.*

2.6 Que-Hellyer Volcanics

Both whole rock and clinopyroxene data for the Que-Hellyer Volcanics are presented in Table 2.6 and plotted in Figure 2.8. The whole rock data plot on a reasonably well constrained isochron on the $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ diagram consistent with an approximate 500 Ma age. This isochron projects through the Cambrian

ore target ellipses. The lowest $^{206}\text{Pb}/^{204}\text{Pb}$ data are from *clinopyroxene leaches from the Hellyer Basalt and have isotopic compositions very similar to the Hellyer target ellipse* (Fig. 2.9). These leaches indicate Pb contents of the clinopyroxenes of up to 48 ppm which is most probably too high to be considered as solid solution within the crystal lattice. However, some of the low- $^{206}\text{Pb}/^{204}\text{Pb}$ pyroxenes have Pb contents as low as 4 ppm which is more consistent with a magmatic Pb component within the crystal structure. An alternative source of this Pb is from hydrothermal alteration, however the minerals are described as unaltered by Tony Crawford (pers comm, 1994). At this stage we conclude that the Pb in the low-Pb clinopyroxenes is magmatic and thus represents the isotopic compositions of the Cambrian basaltic magmas.

2.7 Devonian Granites

Samples of the Round Mountain, Pine Hill and Heemskirk granites were analysed by sequential leach techniques. The results are presented in Table 2.7 and Figure 2.10. The single Pine Hill sample plots within the Renison hydrothermal ellipse suggesting a common origin for the Pb in the hydrothermal and magmatic systems. Although the Pb content of this sample is within normal limits for magmatic K-feldspar, it is possible a component of the Pb derived from hydrothermal alteration. Data from the Round Mountain, and Heemskirk granites are very similar and have significantly higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios than the Queen Hill and Renison hydrothermal signatures. We are confident these data are initial ratios and conclude that there is a significant range in the Pb isotopic signatures of Devonian granites which does not overlap the Cambrian fields. This range in the combined hydrothermal - magmatic signatures of Devonian systems is of similar magnitude to the range in the Cambrian, but displaced to higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios. We note that $^{206}\text{Pb}/^{204}\text{Pb}$ ratios measured in the Heemskirk and Round Mountain granites are higher than any

hydrothermal mineralization and thus the Pb in these Devonian deposits could not have been wholly derived from these granites. Alternative explanations are either that;

- the granites sampled are not representative of the total suite or,
- Pb from the granites mixed with Pb from a lower $^{206}\text{Pb}/^{204}\text{Pb}$ source, possibly the Ordovician or Cambrian Volcanic hosts, during hydrothermal activity.

3. Model to Relate Cambrian Hydrothermal and Magmatic Data

In summary, the results presented above indicate that:

- the Cambrian intrusive rocks and the Que/Hellyer Basalts have initial ratios similar to the Cambrian mineralization and thus are consistent with being the dominant source of Pb, and by analogy other metals, to the hydrothermal fluids.
- neither the Precambrian meta-sedimentary rocks nor the Crimson Creek Formation rocks appear to have been sources of Pb, although a source from a subset of the Precambrian mafic rocks cannot be ruled out based on this data.

It has long been recognised that the Cambrian ore Pb isotope signatures of the Mt Read Volcanics are anomalous in comparison to Cambrian crustal Pb from the Tasman Fold Belt system to the north (Gulson and Porritt, 1987, Carr et al, 1995). In particular the Mount Read Volcanics have;

- high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios of up to 18.3 in contrast to 17.9 for the Cambrian Kanmantoo Fold Belt
- a wide range of $^{206}\text{Pb}/^{204}\text{Pb}$ ratios between

deposits in contrast to the narrow range for the lower Palaeozoic deposits of the Lachlan Fold Belt (LFB) and Mt Windsor Province of the Thompson Fold Belt (TFB)

- $^{207}\text{Pb}/^{204}\text{Pb}$ ratios that plot slightly below average crustal growth curves such as the Cumming and Richards (1975) curve.

Gulson and Porritt (1987) suggested that the anomalously high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios result from derivation of Pb from Precambrian crust enriched in U relative to "average crust". The metallogenic and exploration significance of this model is that the ore fluids must have derived the majority of their Pb, and by analogy other ore elements, from the Precambrian crustal rocks. This "enriched crust model" however would require significantly higher $^{207}\text{Pb}/^{204}\text{Pb}$ ratios than is apparent in the Mt Read mineralization (Figure 2.11).

We present here an alternative model which is consistent with the source rock data described above and explains the anomalous character of the ore Pb. The model is presented in Figure 2.11. The critical elements of the model are:

- The high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, yet low $^{207}\text{Pb}/^{204}\text{Pb}$ ratios, for the Cambrian ores (Rosebery, Que River, Hellyer) require a source that has evolved over a long period of time from source rocks high U/Pb ratios but with low initial $^{207}\text{Pb}/^{204}\text{Pb}$ ratios. The only geologically reasonable source with such geochemical characteristics would be a U enriched mantle with an average isotopic composition in the Cambrian similar to, or with higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, than the Hellyer target ellipse.
- Mixing of this Pb with normal Tasman Orogen Cambrian crustal Pb similar to the Kanmantoo data would account for

the range of $^{206}\text{Pb}/^{204}\text{Pb}$ values between the Hellyer and Elliott Bay end members. Although the Precambrian basement would seem logically to be a source of this crustal Pb, the samples analysed in this study had $^{208}\text{Pb}/^{204}\text{Pb}$ ratios which would suggest otherwise. We thus do not know what rocks in the region may represent this normal Tasman Orogen Cambrian crust. Such mixing is not as apparent in the Lachlan Fold Belt and Mt Windsor province because there is little Pb isotopic contrast between the regional sedimentary rocks (commonly Ordovician metasediments) and the acid volcanic magmas, derived by intra-crustal melting.

This "enriched mantle model" model requires that the Que River - Hellyer Basalts represent melts derived from mantle that has undergone enrichment in U relative to Pb at some stage in the Precambrian and that these melts had Pb isotopic ratios similar to, or with higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, than the Hellyer target signature. The data presented above for the Que-Hellyer Basalts are consistent with this interpretation. Also the Precambrian Granites, which have more crustal geochemical and Sr - Nd isotope signatures, have slightly lower initial $^{206}\text{Pb}/^{204}\text{Pb}$ ratios than the Que - Hellyer Basalts suggesting a slightly higher crustal Pb component. Such a model compares closely with the crust-mantle mixing model of Carr et al. (1995) for the Lachlan Fold Belt but with a distinctly more U enriched mantle source region.

4. Genetic and Exploration Implications of a Mantle-Crust Mixing Model

This interpretation of the Pb isotope data implies that in the major ore systems of the region, i.e. Que River, Hellyer and Rosebery, metals were derived principally from a

magmatic system with strong mantle affinities. In this system there is no requirement for metals to have been derived from the Proterozoic basement and indeed it can be shown that the metasedimentary basement rocks have Pb isotopic compositions which are inconsistent with them being a source of Pb. An implication of this conclusion is that the magmatic protolith, in addition to having relatively high U/Pb ratios must also have been significantly enriched in Pb (10 - 20 ppm) relative to normal basaltic rocks (~ 1 ppm). Such enrichment is not uncommon in shoshonitic basalts, e.g., Goonumbla Volcanics, Heithersay and Walshe, 1995). An important question regarding the significance of this "enriched mantle model" is:

\$ Is the mantle association critical to the formation of the very large base metal ore deposits?

Further south, in the Elliott Bay region there is mineralization which is similar in style to Que River, Hellyer and Rosebery, but to date no major deposits have been discovered. This mineralization appears to have a much closer affinity with Tasman Orogen crustal Pb, although it is still isotopically anomalous in comparison to the LFB and TFB VHMS mineralization. There is thus an apparent correlation between the size of the ore systems and the crust - mantle affiliation. We could not suggest that the crustal rocks are less fertile as a potential source of Pb, however the larger crustal Pb component is likely to be indicative of a different tectonic environment, and it is this which may be significant in determining the nature and size of hydrothermal systems.

It is our proposal that within the overall tectonic context of the Mount Read Volcanic terrain, the association with substantially mantle derive Pb is critical to the formation of major massive sulfide mineralization. *Therefore an exploration model that incorporated a search for the most mantle-like hydrothermal signatures in the terrain would seem to have the highest probability of success.* Such a model

should apply throughout the terrain.

5. Distinction between Cambrian and Devonian signatures

The distinction in Pb isotope signatures between Cambrian and Devonian hydrothermal events described previously by Gulson et al. (1987) also holds for the intrusive magmatic suites of the region. *Thus we are more confident that these signatures do not overlap and that they can thus be used to distinguish Devonian and Cambrian mineralization.* The results are, however, somewhat enigmatic in that the Devonian granites have much higher $^{206}\text{Pb}/^{204}\text{Pb}$ ratios than would be expected if they had derived from a similar source to the Cambrian granites, 100 Ma later. A possible explanation is that the Devonian granites derived a higher proportion of their Pb from the high $^{206}\text{Pb}/^{204}\text{Pb}$, enriched mantle source than did the Cambrian granites.

Confidentiality

The data and results of this study will be the property of Aberfoyle Resources Ltd. Although it is anticipated that the Pb isotope data will be discussed with Drs Graham Carr, Brian Gulson and Joe Stolz, Prof. Ross Large and Judy Dean to properly evaluate the data, this information will remain confidential.

As the results of this research may lead to an exploration advantage for Aberfoyle Resources Ltd, no publication of results arising from the Elliott Bay, source-rock or Mackintosh District investigations will be made for two years from the end of the project. It was agreed that the Hellyer mineralisation data will be open and available for publication immediately after it has been reported to Aberfoyle (in practice publication will take 12-18 months).

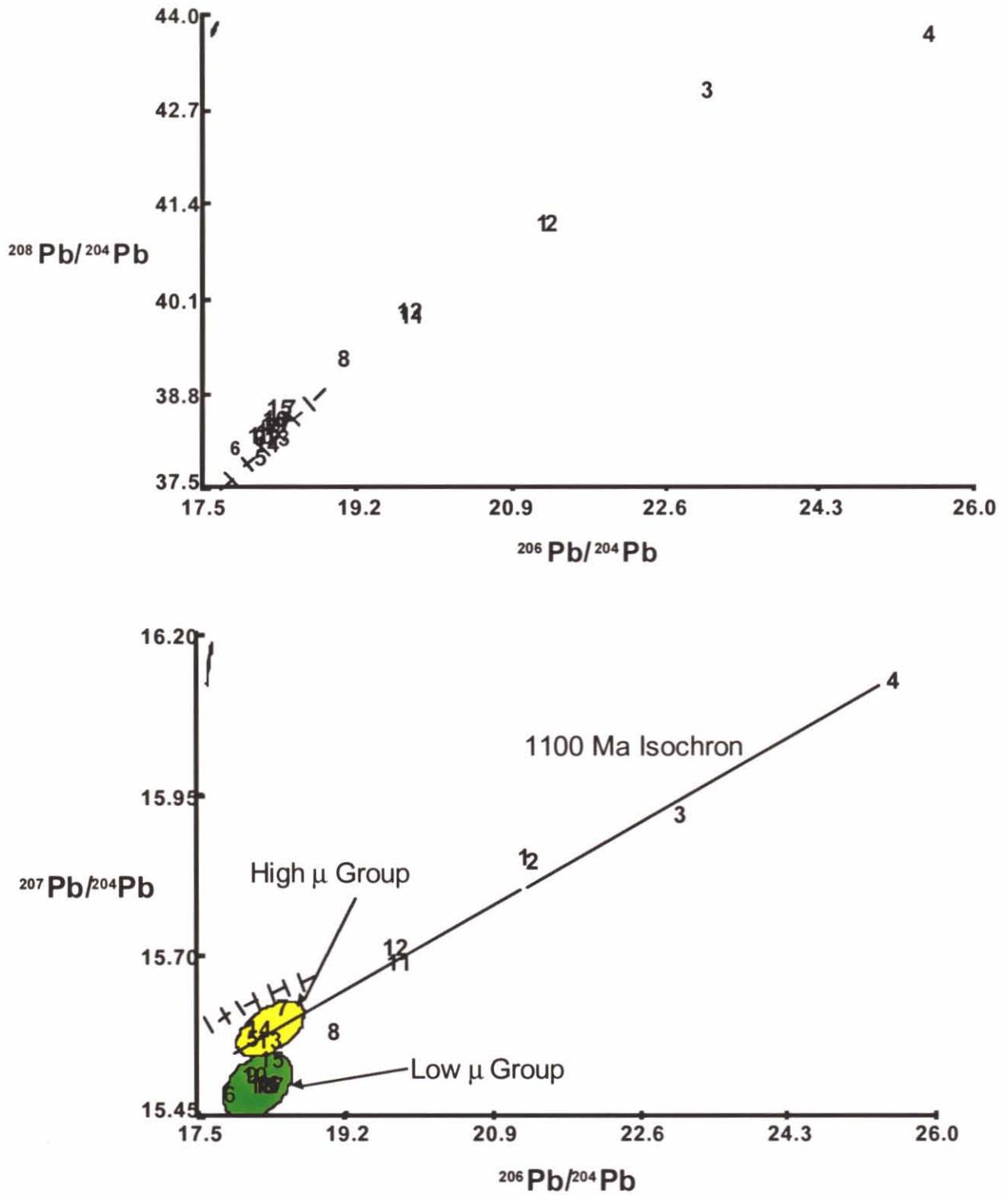


Figure 2.1

Lead isotope ratio plots showing data for Precambrian mafics obtained by Brian Gulson. The data were all obtained from low-Pb samples (see Table 2.1) and are thus all considered to contain significant radiogenic Pb derived in situ since the Precambrian. The isochron through the high μ group indicates an apparent age of 1070 ± 100 Ma. Coloured fields for the high μ group (yellow) and the low μ group (green) are also shown.

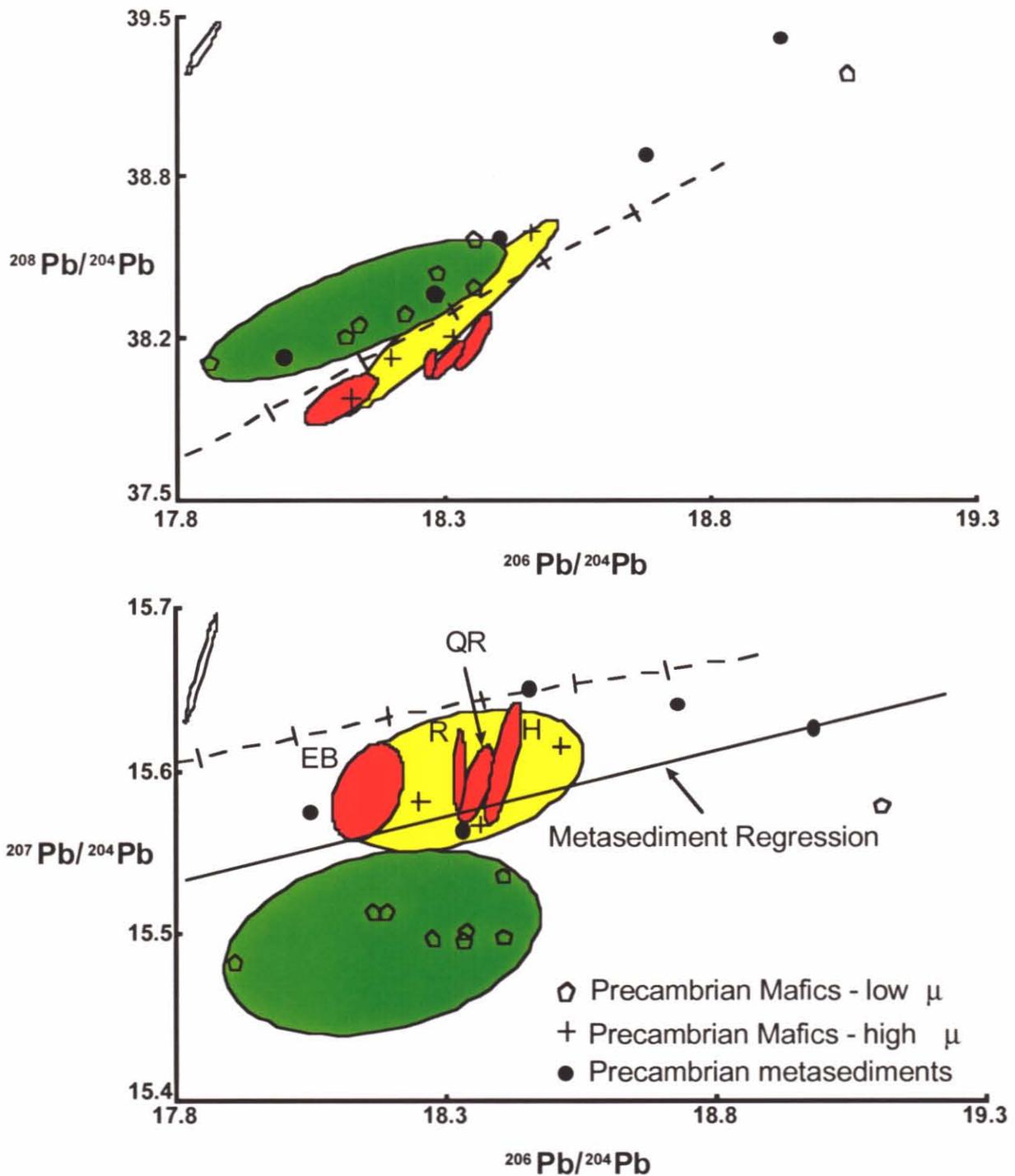


Figure 2.2

Expanded scale lead isotope ratio plots showing data from Figure 2.1 in comparison to the Cambrian massive sulfide deposits (H = Hellyer, QR = Que River, R = Rosebery, EB = Elliott Bay) and Precambrian metasedimentary rocks. Coloured fields are as in Figure 2.1.

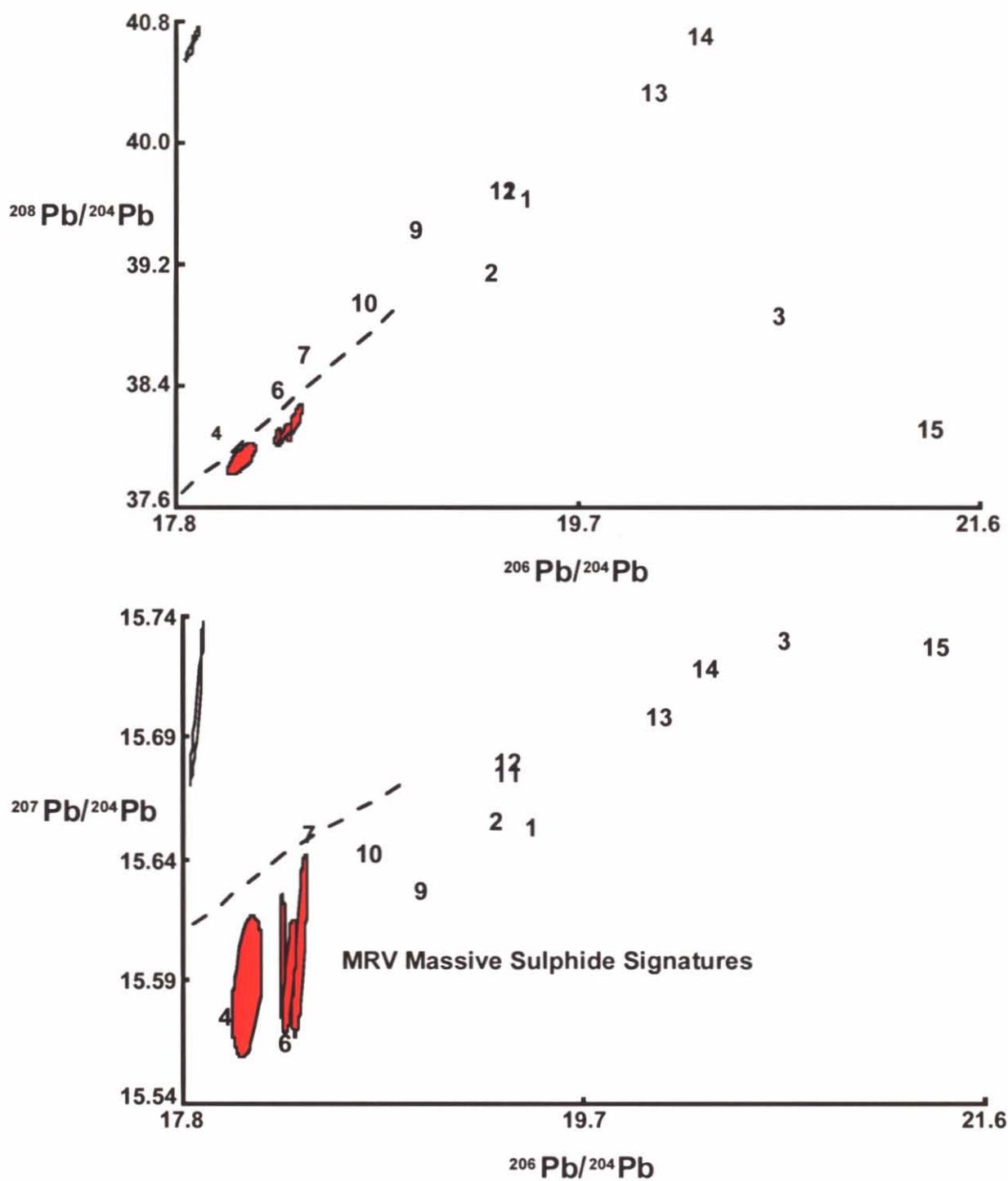


Figure 2.3

Lead isotope ratio plot of Precambrian metasedimentary rock data in comparison to the signatures for Cambrian massive sulphide deposits (see Fig. 2.2). The numbers refer to the data in Table 2.2.

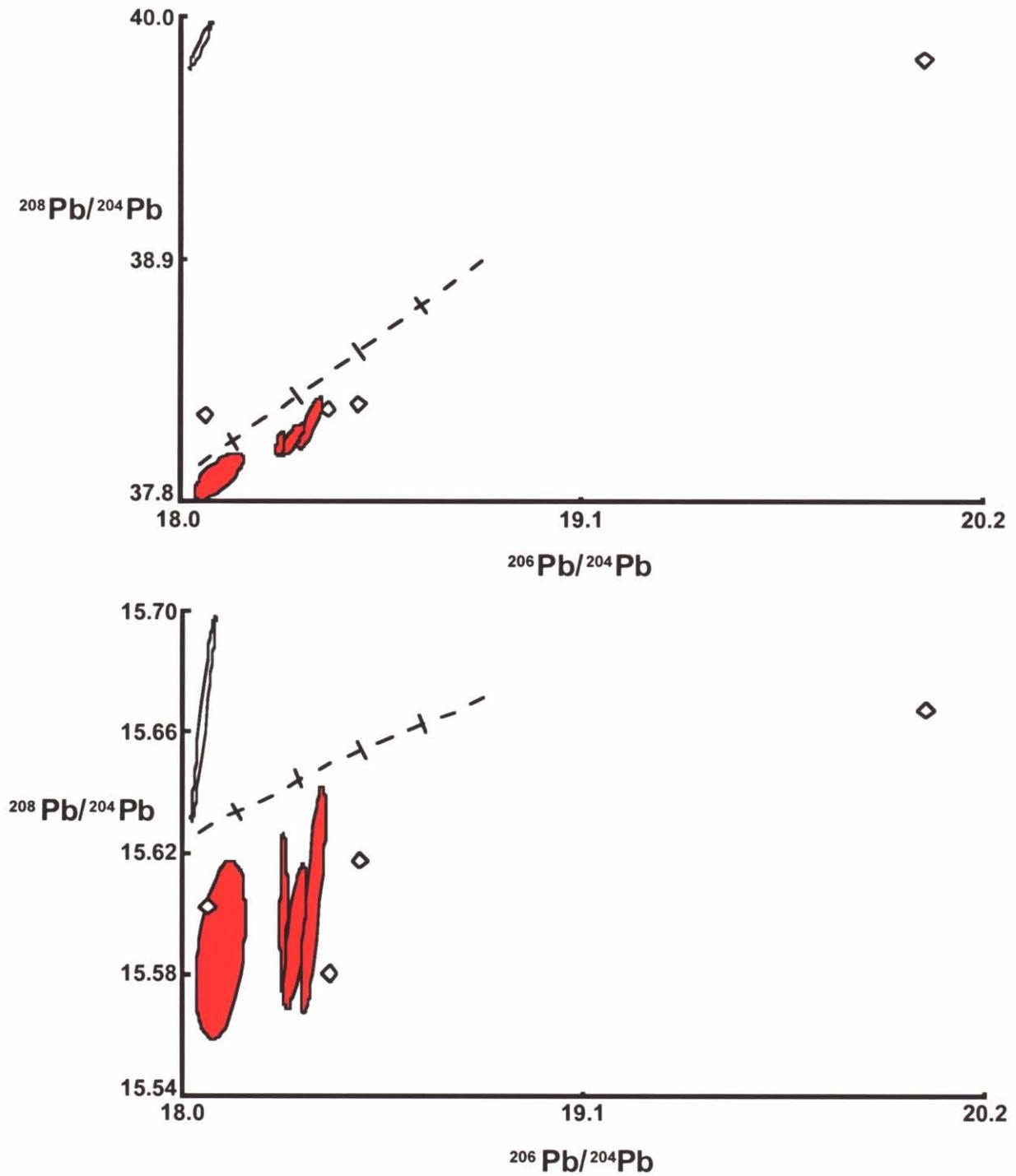


Figure 2.4

Lead isotope ratio plot of Crimson Creek Formation samples in comparison to the signatures for Cambrian massive sulphide deposits (see Fig. 2.2). Data from Table 2.3.

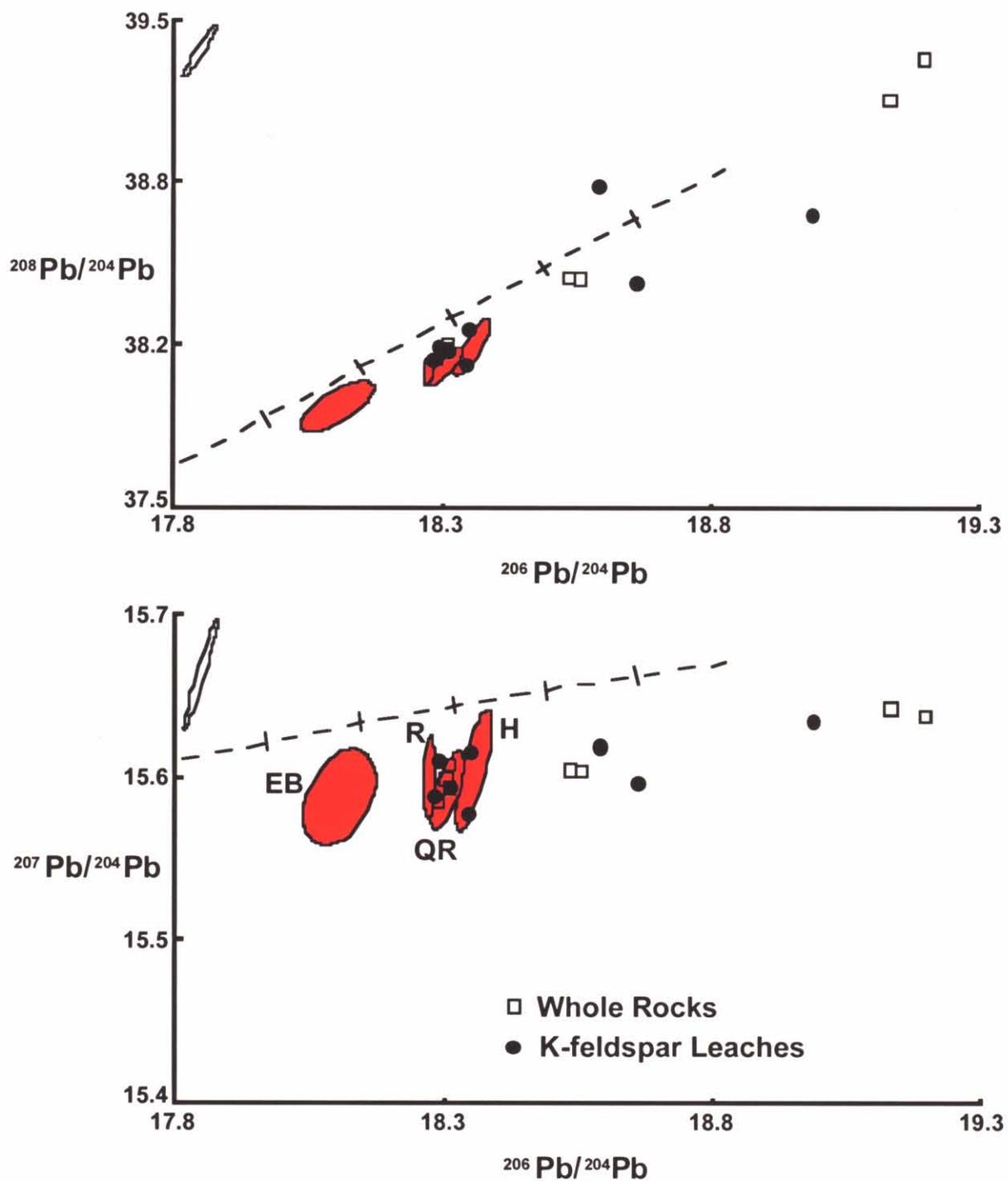


Figure 2.5

Lead isotope ratio plot of Cambrian intrusive rocks in comparison to the signatures for Cambrian massive sulphide deposits (see Fig. 2.2). Data from Table 2.4.

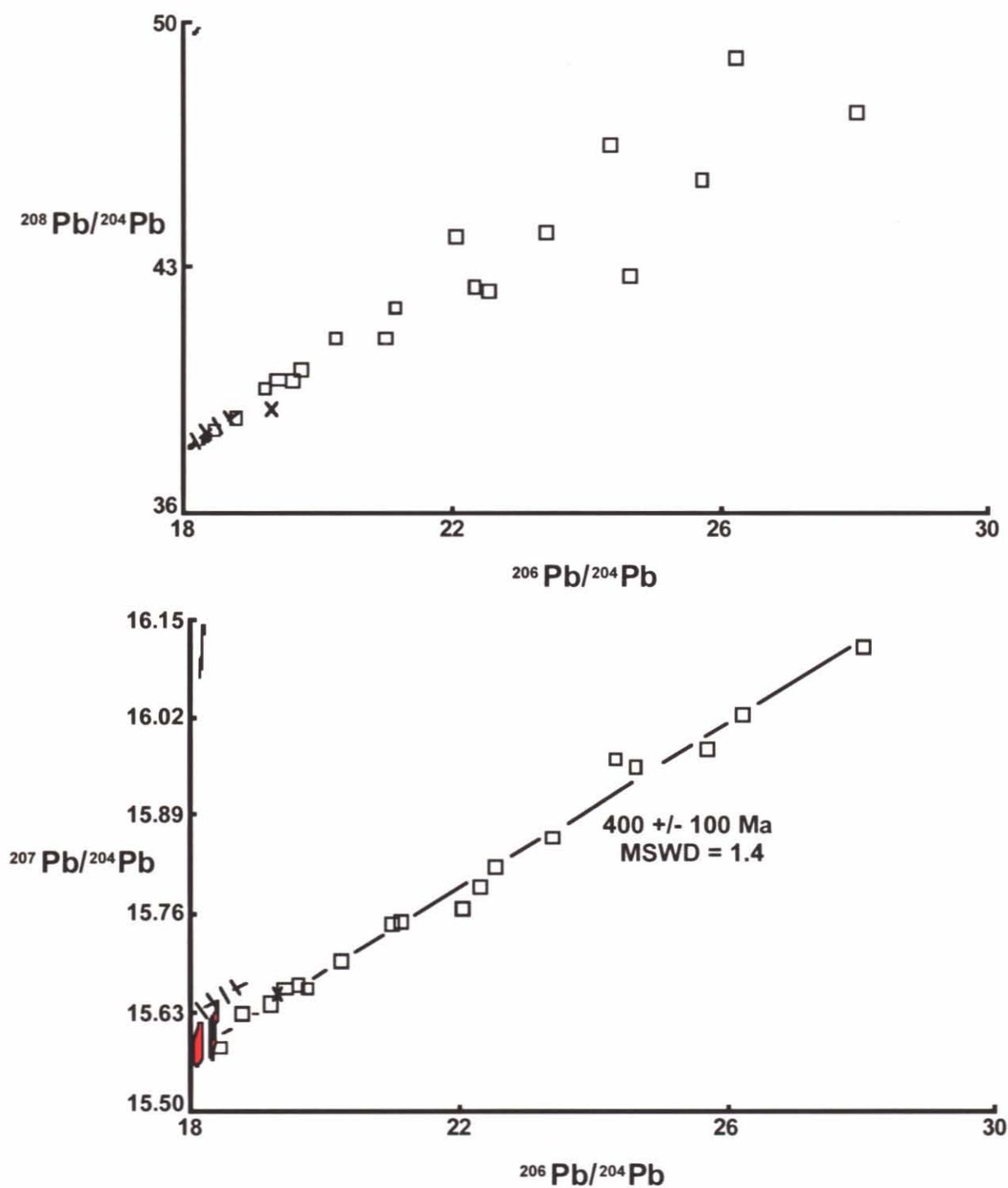


Figure 2.6

Lead isotope ratio plot of Central Volcanic Complex samples in comparison to the signatures for Cambrian massive sulphide deposits (see Fig. 2.2). All data are whole rock analyses except for single K-feldspar leach (cross). Data from Table 2.5.

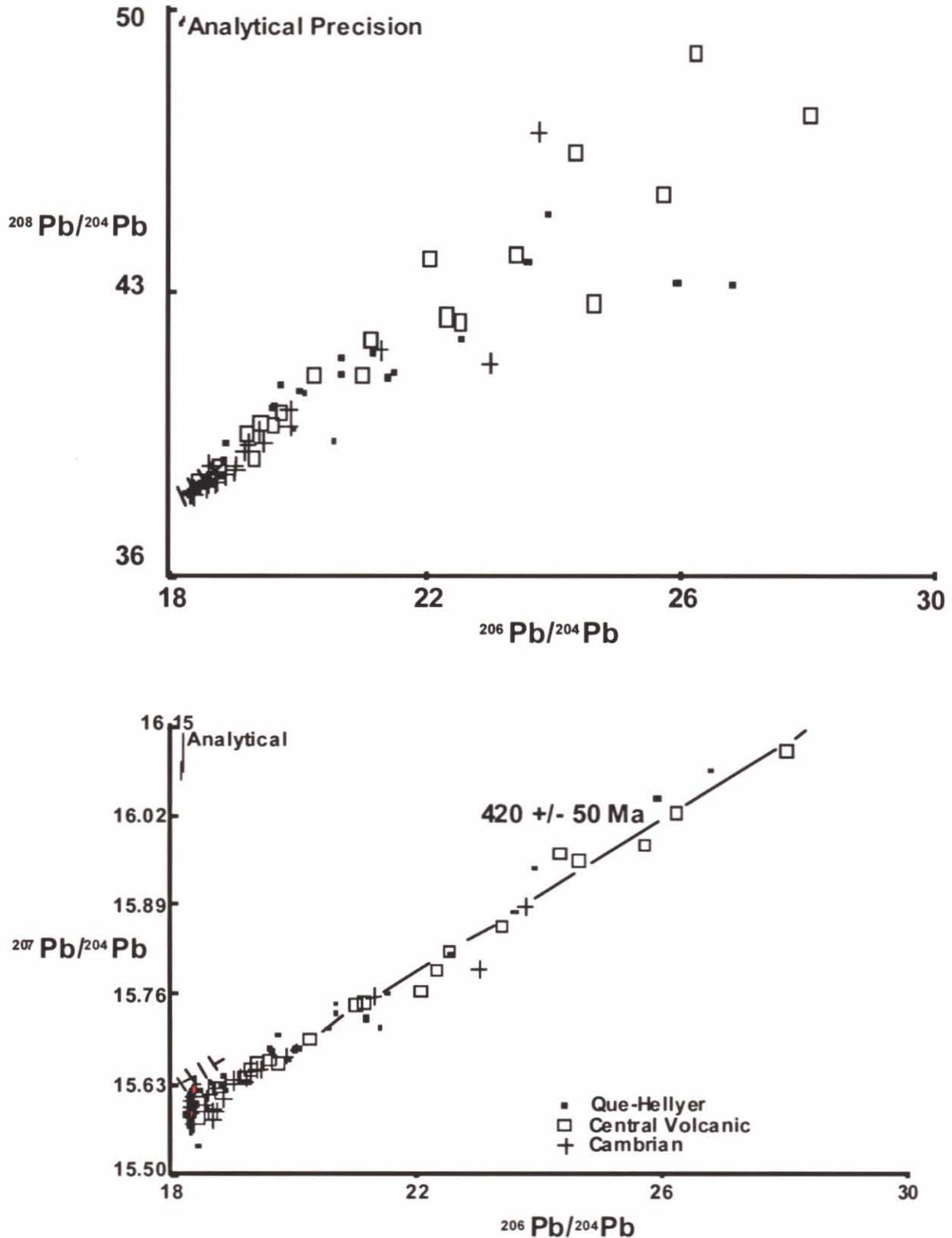


Figure 2.7

Lead isotope ratio plot comparing all data from the Que-Hellyer Volcanics, the Central Volcanic Complex and the Cambrian Intrusives. The combined data lie on an apparent isochron with a good MSWD of 1.3 suggesting they are all colinear. The isochron projects through the 95% confidence ellipses for the Mt Read massive sulfide mineralization (in red).

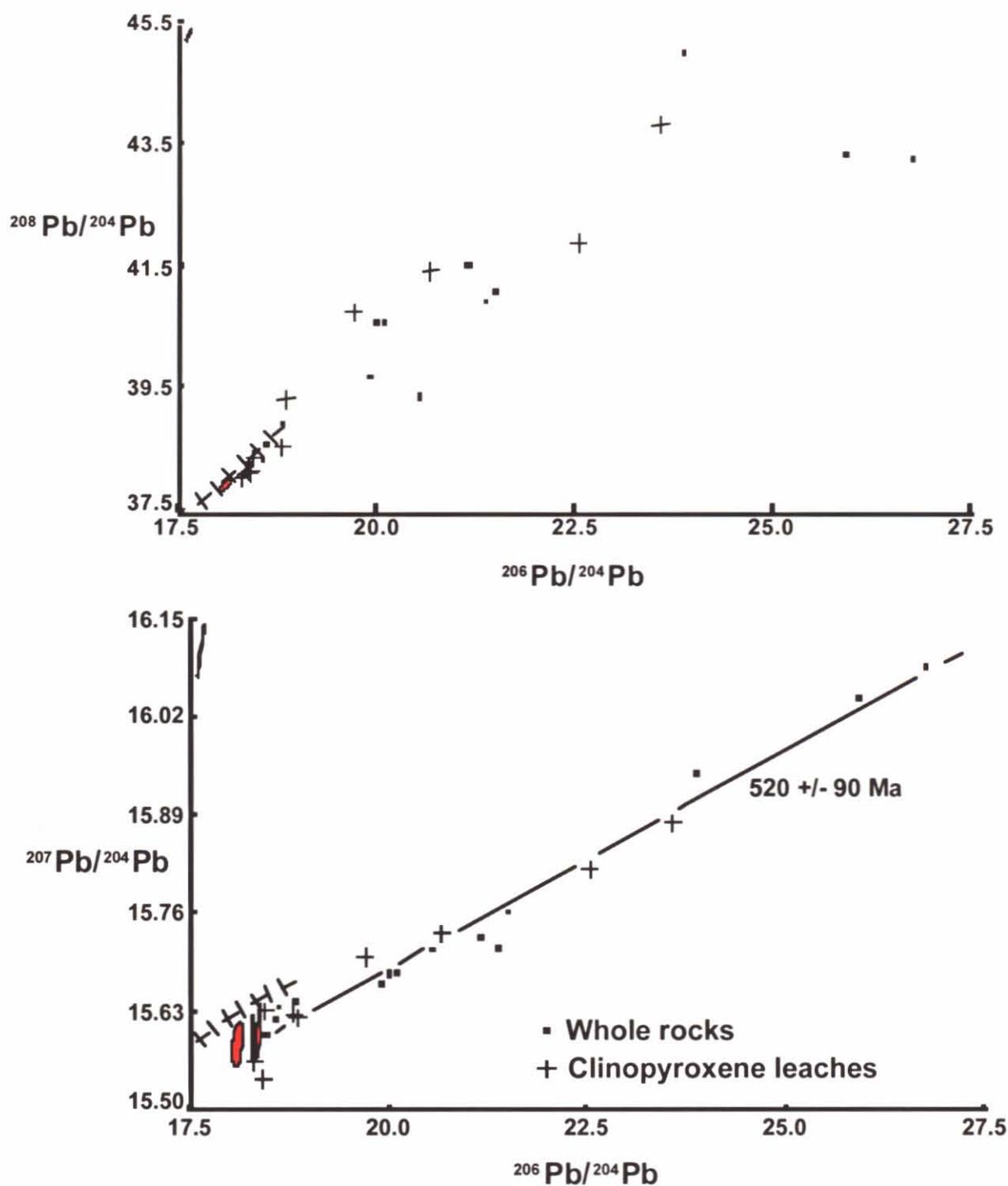


Figure 2.8

Lead isotope ratio plot of Que - Hellyer Volcanics in comparison to the signatures for Cambrian massive sulphide deposits (See Fig. 2.2). Data from Table 2.6.

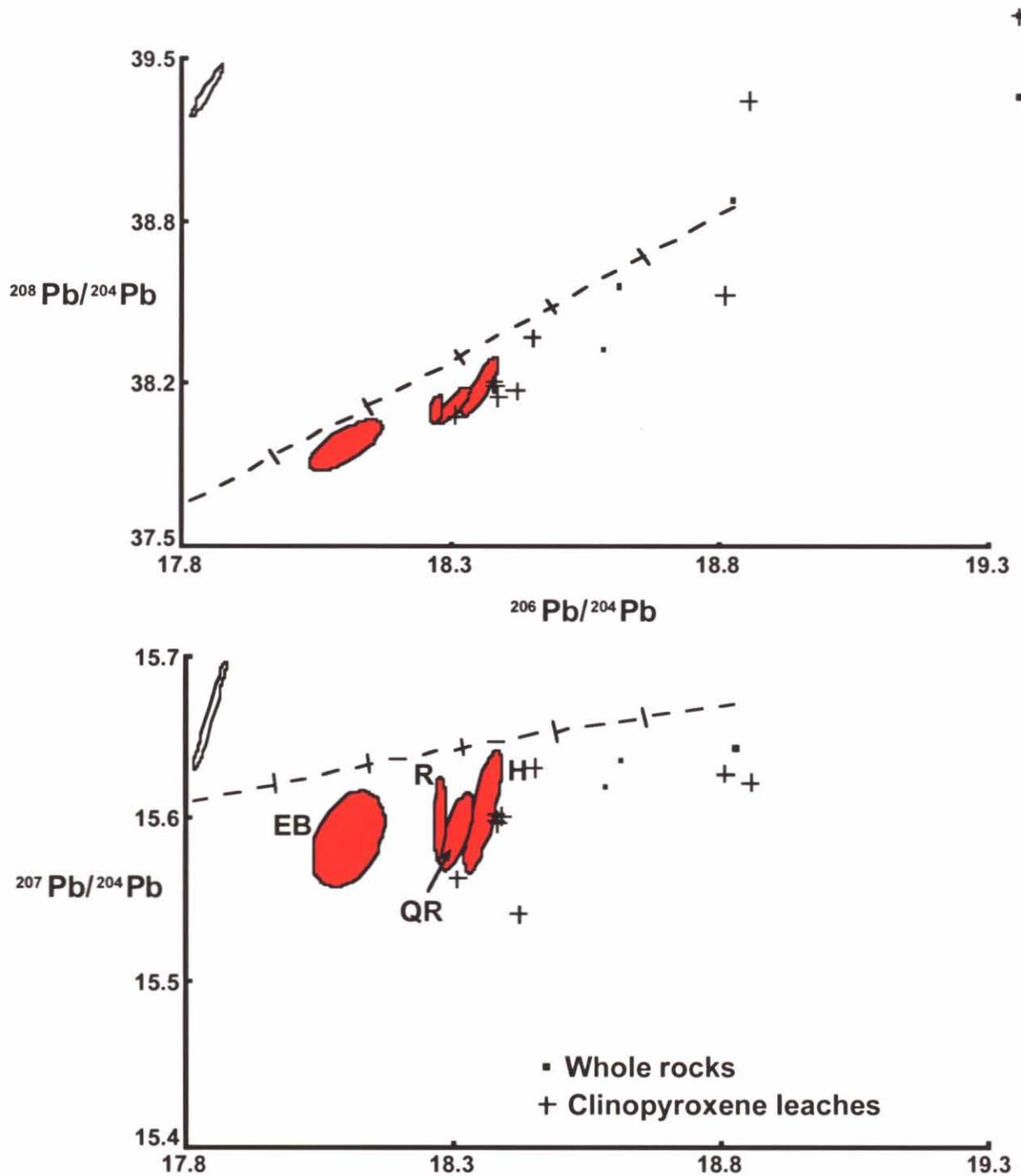


Figure 2.9

Expanded scale Pb isotope ratio plot of Que - Hellyer Volcanics in comparison to the signatures for Cambrian massive sulphide deposits (see Fig. 2.2).

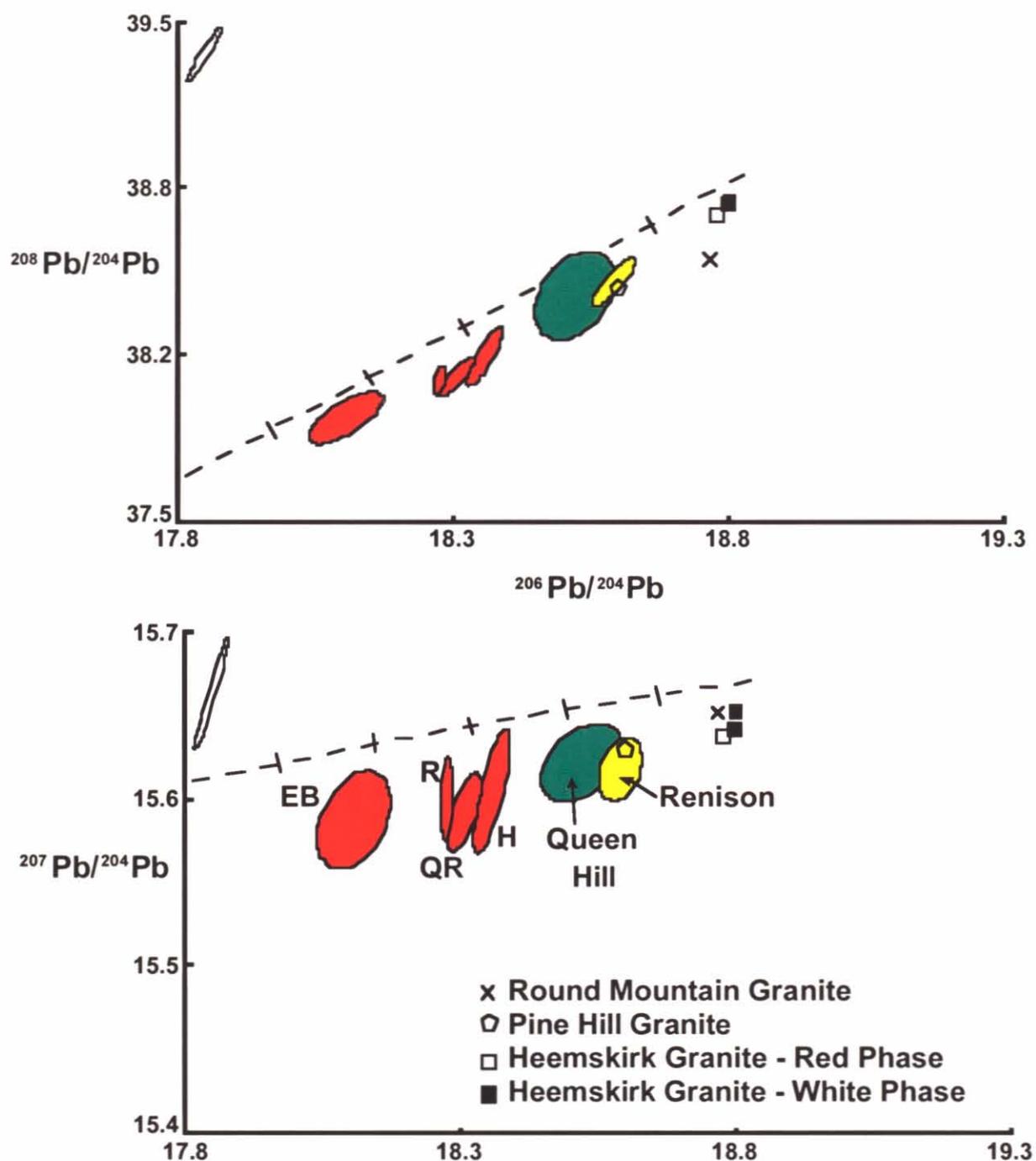


Figure 2.10

Lead isotope ratio plot of Devonian granite samples in comparison to the signatures for Cambrian massive sulfide deposits (see Fig. 2.2) and Devonian hydrothermal mineralisation from Queen Hill and from Renison.

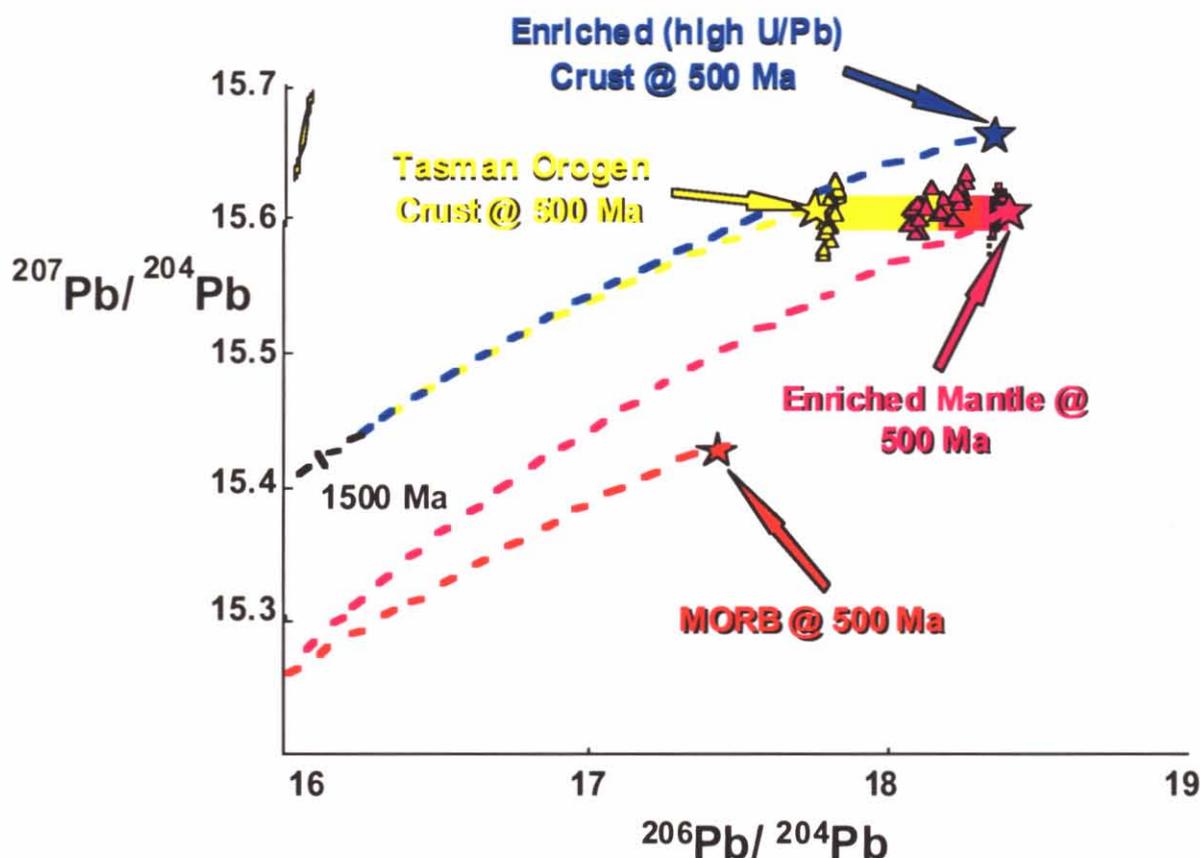


Figure 2.11

Lead isotope ratio diagram showing diagrammatically the various models to explain the Mount Read data (Red squares = Hellyer; magenta triangles = Elliott Bay; yellow triangles = Kanmantoo massive sulfides).

- In the *"Enriched Crust Model"* the high $^{206}\text{Pb}/^{204}\text{Pb}$ ratios of the Hellyer ores would be explained by derivation of Pb from Proterozoic (~ 1100 Ma) crust. However, such Pb would have evolved along a growth curve similar to that in blue above and at 500 Ma would have had a high $^{207}\text{Pb}/^{204}\text{Pb}$ ratio, represented by the blue star. The normal Tasman Crust at this stage had isotopic ratios similar to the Kanmantoo mineralization and is represented by the yellow star. The Hellyer ore Pb isotope ratios cannot be explained by such a source unless it is postulated that mixing occurred with another reservoir with similar $^{206}\text{Pb}/^{204}\text{Pb}$ ratios, but lower $^{207}\text{Pb}/^{204}\text{Pb}$ ratios. No such reservoir has been identified in this study.
- In the *"Enriched Mantle Model"*, Pb would have been derived from a modified MORB source which was enriched in Pb and U at some time at least several hundred million years prior to the Cambrian mineralizing event. Overall the U/Pb ratio of this modified mantle was significantly higher than MORB and the Pb evolved on a growth curve similar to that in magenta above. The $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios of this enriched mantle in the Cambrian have been defined by the initial ratios of the pyroxenes and are very similar to the Hellyer data (magenta star). Mixing of this Pb with Tasman Crustal Pb (yellow star) accounts for the range in $^{206}\text{Pb}/^{204}\text{Pb}$ ratios observed in the Mt Read mineralization and is represented on the diagram by the magenta-to-yellow coloured field.

Table 2.1

Sample descriptions, Pb isotope ratios and Pb contents of Precambrian mafic metavolcanic rocks from western Tasmania. Plot groups "H" and "L" are discussed in the text and plotted in Figure 2. 1.

Plot No.	Sample No.	Unit	Rock Type	206/204	207/204	208/204	Plot Grp	Pb (ppm)
1	NB 134	Nye Bay Metamorphics	Amphibolite	21.236	15.850	41.121	H	-
2	NB 134	Nye Bay Metamorphics	Amphibolite	21.345	15.847	41.127	H	5.70
3	RL 1	Arthur Lineament	Amphibolite	23.056	15.920	42.944	L	-
4	RL 1	Arthur Linament	Amphibolite	25.503	16.127	43.717	L	2.2
5	SC 1	Sassy Creek	Greenstone	18.123	15.571	37.923	H	-
6	NC 29	Savage River	Metabasalt	17.858	15.483	38.067	L	1.3
7	NC 30	Savage River	Metabasalt	18.463	15.616	38.608	H	4.4
8	NC 35	Savage River	Metabasalt	19.056	15.579	39.265	L	0.5
9	NC34	Bernafai Volcanics	Metabasalt	18.113	15.514	38.173	L	3.3
10	NC34	Bernafai Volcanics	Metabasalt	18.138	15.514	38.225	L	3.1
11	NC269	Bernafai Volcanics	Metabasalt	19.808	15.688	39.862	L	3.3
12	NC269	Bernafai Volcanics	Metabasalt	19.774	15.712	39.909	L	3.8
13	NC8	Corinna district	Gabbro	18.313	15.568	38.174	H	1.9
14	NC8	Corinna district	Gabbro	18.201	15.583	38.094	H	151
15	NC174	Bernafai Volcanics	Gabbro	18.355	15.536	38.578	L	1.1
16	NC174	Bernafai Volcanics	Gabbro	18.286	15.502	38.438	L	1.1
17	NC506	Bernafai Volcanics	Gabbro	18.355	15.499	38.377	L	0.9
18	NC508	West Coast	Gabbro	18.224	15.498	38.272	L	1.1
19	NC508	West Coast	Gabbro	18.282	15.497	38.348	L	1.1

Table 2.2

Lead isotope ratios of metasedimentary rocks from western Tasmania. All samples analysed by whole rock method.

Plot No	Sample No.	Rock Type	Location	205/204	205/204	205/204
1	20/7-1	Black shale	Lyell Hwy Trav.	19.450	15.652	39.603
2	20/7-2	Black shale	Lyell Hwy Trav.	19.290	15.655	39.119
3	20/7-3	Py carb Qtzite and shale	Lyell Hwy Trav.	20.648	15.729	38.840
4	20/7-4	Black phyllite and Qtzite	Lyell Hwy Trav.	17.999	15.575	38.088
5	20/7-5	Quartzite	Lyell Hwy Trav.	22.133	15.928	41.815
6	20/7-6	Eclogite	Lyell Hwy Trav.	18.282	15.564	38.352
7	20/7-8	Limestone	Lyell Hwy Trav.	18.405	15.650	38.583
8	NB 32	Garnet Schist	Nye Bay Met.	33.819	16.844	61.053
9	NB 87	Grey Phyllite	Nye Bay Met.	18.932	15.626	39.405
10	SC 2	Dolomite phyllite	Sassy Crk	18.679	15.641	38.927
11	21/7-11	Quartzite	Oonah Quartzite	19.334	15.675	39.669
12	21/7-11	Quartzite	Oonah Quartzite	19.336	15.679	39.677
13	21/7-12	Quartzite	Oonah Quartzite	20.063	15.698	40.307
14	21/7-13	Black Phyllite	Oonah Quartzite	20.276	15.717	40.676
15	NC 204	Dolomite	Corinna district	21.368	15.726	38.101

Table 2.3

Lead isotope results for Crimson Creeek Formation

Sample no.	Location	Rock type	Analytical method	206/204	207/204	208/204	Pb (ppm)
LD 86-1A	Luina	argillite	WR	18.067	15.603	38.197	37
LD 86-1E	Luina	basalt	WR-HF	18.484	15.618	38.246	4.7
LD 86-1E	Luina	basalt	WR	18.402	15.581	38.221	2.8
LD 86-1E	Luina	basalt	WR	20.036	15.667	39.806	0.5

WR, whole rock; HF, hydrofluoric acid leach (see methods section for details)

Table 2.4

Lead isotope data of Cambrian intrusive rocks.

Sample no.	Location	Analytical Method	206/204	207/204	208/204	Pb (ppm)
LS12	Lake Selina	Kfs - L	18.286	15.587	38.100	10
LS12/A	Lake Selina	Kfs - L	18.351	15.615	38.230	-
LS12/A	Lake Selina	Kfs - L	18.591	15.618	38.816	19
16066	Back Peak	Kfs - L	18.661	15.596	38.417	-
16069	Murchison	Kfs - L	18.313	15.593	38.138	50
16069	Murchison	Kfs - L	18.293	15.610	38.155	-
16069	Murchison	Kfs - L	18.344	15.577	38.080	-
EB1	Elliott Bay	Kfs - L	18.989	15.633	38.697	-
75280071	Murchison	WR	18.309	15.609	38.173	330
75280071	Murchison	WR	18.307	15.595	38.142	-
75280072	Murchison	WR	18.302	15.600	38.153	602
75280072	Murchison	WR	18.290	15.586	38.108	-
75280073	Murchison	WR	19.437	15.655	39.379	-
75280073	Murchison	WR	19.840	15.673	40.185	8
75280074	Murchison	WR	19.194	15.637	39.340	-
75280074	Murchison	WR	19.378	15.656	39.655	13
75280075	Murchison	WR	18.553	15.604	38.438	-
75280076	Murchison	WR	19.131	15.643	39.173	-
75280075	Murchison	WR	18.535	15.605	38.441	78
75280077	Murchison	WR	21.275	15.759	41.648	5
75280077	Murchison	WR	19.843	15.674	39.777	-

WR, whole rock; Kfs-L, potassium feldspar, sequential acid leach (see methods section for details)

Table 2.5

Lead isotope results for Central Volcanic Complex rocks

Sample no.	Location	Rock type	Analytical method	206/204	207/204	208/204	Pb (ppm)
AR11	Anthony Road	andesite	Kfs - L	24.676	15.986	41.379	0.8
71RC	N of Rosebery	Rhyodacite	WR	19.288	15.655	38.940	2.9
BR 1/A	Bradshaws road	basalt	WR	18.748	15.629	38.724	1.7
WS 4	Mt Huxley	andesite	WR	21.129	15.751	41.849	7.4
WS 4	Mt Huxley	andesite	WR	22.045	15.767	43.903	1.0
HX 1	Mt Huxley	rhyolite	WR	21.816	15.765	43.397	3.3
HX 1	Mt Huxley	rhyolite	WR	28.018	16.116	47.404	0.6
MR 1/A	Mt Read	dacite	WR	18.427	15.584	38.370	17
MR 1/A	Mt Read	dacite	WR	23.394	15.863	43.994	0.91
H 955/A	Rosebery	rhyolite	WR	19.583	15.666	39.758	13.9
H 955/A	Rosebery	rhyolite	WR	20.988	15.748	40.954	1.6
80 RB	Rosebery	dacite	WR	25.698	15.978	45.486	1.2
RED 871/B	Rosebery	dacite	WR	22.307	15.797	42.428	2.9
PPR/B	Rosebery	dacite	WR	19.718	15.662	40.052	6.2
PPR/F	Rosebery	rhyodacite	WR	26.213	16.026	48.931	18.9
85R/A 1	Rosebery	rhyolite	WR	24.323	15.967	46.474	2.3
85R/A	Rosebery	rhyolite	WR-HF	22.528	15.823	42.294	-
BD269/A	Rosebery	dacite	WR	19.188	15.642	39.523	8.0
BP272/C	Rosebery	rhyolite	WR	19.391	15.663	39.778	18.4
BP272/C	Rosebery	rhyolite	WR-HF	24.616	15.956	42.786	1.52
AR 11	Anthony Road	andesite	WR	20.250	15.697	40.971	7.8

Table 2.6
Lead isotope ratios of Que-Hellyer Volcanics whole rock and clinopyroxene leaches

Sample no.	Location	Rock type	Analytical method	206/204	207/204	208/204	Pb (ppm)
73940	Que-Hellyer voics	basalt	cpx - L	18.308	15.564	38.040	0.2
Z7250*	Sock Ck	basalt	cpx - L	18.854	15.622	39.325	0.4
Z7250*	Sock Ck	basalt	cpx - L	18.382	15.598	38.164	4.6
Z7250*	Sock Ck	basalt	cpx - L	18.378	15.603	38.165	3.7
MC1B	Mt Charter	basalt	cpx - L	22.529	15.819	41.884	1.2
MC1B	Mt Charter	basalt	cpx - L	23.572	15.882	43.830	1.2
MC1D	Mt Charter	basalt	cpx - L	18.388	15.602	38.114	47
MAC30 274.3*	Mackintosh lease	basalt	cpx - L	18.420	15.542	38.140	25
MAC30 551.3*	Mackintosh lease	basalt	cpx - L	18.381	15.599	38.179	6.2
MAC35 308.5*	Mackintosh lease	basalt	cpx - L	18.809	15.628	38.535	2.8
BRD 1 534.6*	Bradshaws Road	basalt	cpx - L	20.666	15.734	41.425	1.3
Z7247*	Sock Ck	basalt	cpx - L	18.450	15.632	38.360	0.6
Z7252*	Sock Ck	basalt	cpx - L	19.710	15.703	40.758	0.4
MAC 5A	Mackintosh lease	andesite	WR	20.548	15.712	39.349	2.0
QR 1001/A	Que River	andesite	WR	20.002	15.681	40.576	1.2
QR 97/A	Que River	rhyolite	WR	21.496	15.762	41.073	2.5
QR 97/C	Que River	andesite	WR	19.924	15.669	39.694	2.2
MC 1/A	Mt Charter	shale	WR	26.778	16.087	43.243	7.7
MAC 10/E	Mackintosh lease	Animal Ck greywacke	WR	18.826	15.644	38.921	4.5
MAC 10/E	Mackintosh lease	Animal Ck greywacke	WR -HF	25.915	16.046	43.319	1.6
MAC 10/A	Mackintosh lease	Hellyer basalt	WR	20.094	15.682	40.550	25
MAC 10/B	Mackintosh lease	footwall andesite	WR	18.613	15.636	38.569	75
MAC 10/B	Mackintosh lease	footwall andesite	WR-HF	21.158	15.728	41.533	2.4
MC 1/A	Mt Charter	black shale	WR	18.583	15.620	38.306	44
QFP 31235	Sock Creek	qtz-feld porphyry	WR	23.879	15.947	44.987	2.4
QFP 31235	Sock Creek	qtz-feld porphyry	WR-HF	21.378	15.715	40.922	0.7

WR, whole rock; HF, hydrofluoric acid leach; cpx-L, clinopyroxene, sequential acid leach (see methods section for details)

Table 2.7
Lead isotope results for Devonian granites

Sample No	Granite	Analytical method	206/204	207/204	208/204	Pb (ppm)
562181	Round Mt	Kfs - L	18.727	15.631	38.475	33
562181	Round Mt	Kfs - L	18.766	15.652	38.552	36
562181	Round Mt	Kfs - L	18.728	15.626	38.453	33
562182	Round Mt	Kfs - L	30.625	15.606	53.308	0.5
562182	Round Mt	Kfs - L	32.843	15.969	56.341	0.5
562182	Round Mt	Kfs - L	32.482	15.855	55.821	0.5
562182	Round Mt	Kfs - L	25.538	15.759	47.113	0.8
562183	Round Mt	Kfs - L	21.068	15.759	39.426	3.4
562183	Round Mt	Kfs - L	19.173	15.689	39.434	25.2
562183	Round Mt	Kfs - L	19.131	15.661	39.343	24.4
61705	Pine Hill	Kfs - L	18.597	15.631	38.434	18.6
61705	Pine Hill	Kfs - L	18.603	15.629	38.448	20.9
67583	Heemskirk	Kfs - L	18.775	15.638	38.728	14.1
67599	Heemskirk	Kfs - L	18.900	15.653	38.780	11.7
67599	Heemskirk	Kfs - L	18.796	15.642	38.771	12.1

Kfs-L, potassium feldspar, sequential acid leach (see methods section for details)

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