M.I.M. EXPLORATION PTY. LTD.

TECHNICAL REPORT

No. 1937

TITLE:	EXPLORATION LICENCE No. 7233 " St Vidgeon " N.T. SECOND ANNUAL REPORT : NOVEMBER 1992
ISSUING DEPARTMENT:	EXPLORATION
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DATE :	NOVEMBER 1992

CR92/639

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APPENDIX

FIGURE

EXPLORATION LICENCE No.7233 "ST VIDGEON" N.T.

SECOND ANNUAL REPORT : YEAR ENDED 10TH JANUARY 1993

1. INTRODUCTION AND SUMMARY

This report describes the work carried out by M.I.M. Exploration Pty. Ltd. on Exploration Licence No. 7233 during 1992.

The Licence is located immediately south of the Roper River on the former St Vidgeon Station. It was granted to Mount Isa Mines Limited on the 10th January 1991 for a term of six years.

Most of the E.L. overlies the central part of the Urapunga Tectonic High, part of the McArthur Basin. Major north-south and east-west faults converge in the Exploration Licence. Both McArthur Group (Vizard Formation) and Nathan Group (Balbirini Dolomite) occur in the Licence and are prospective for copper and lead- zinc deposits.

A letter of agreement with Stockdale Prospecting Limited was signed on the 6th June 1991. This gave permission for Stockdale Prospecting Limited to carry out exploration work for diamonds within the Licence. They have carried out no exploration this year on the Licence.

As reported in the first annual report for E.L. 7233, an anomalous copper-lead zone named the "Mt Birch Prospect" was defined by rock chip and soil sampling. This area however was found by the Aboriginal Areas Protection to be in the vicinity of a number of sacred sites and all fieldwork on the Licence ceased.

Two visits were made to talk to the traditional guardians of the area to try and establish if further exploration work could be carried out. The situation became complicated by other groups in the region wanting to have influence over whatever might be done.

Five rock chip samples collected earlier from two locations were sent for lead isotope study. The results indicate that the mineralisation is highly radiogenic and is most likely of an epigenetic style.

2. LOCATION AND ACCESS

Exploration Licence No. 7233 is located immediately south of the Roper River on St Vidgeon Station about 500km SE from Darwin, N.T. It comprises 169 blocks with a total area of 544 square kilometres.

The location of E.L. 7233 is shown on Figure 1 (Drawing No. 33504).

The Exploration Licence is located on the Urapunga 1:250 000 geological sheet (SD53-10) and on the 1:100 000 Urapunga topographic sheet (5868).

Access to the northern part of the Licence is via the Roper Highway from Mataranka and the Nathan River Road from the Roper Bar turn-off. A track which turns southeast about 1km east of the Queensland Crossing on the Hodgson River allows access to the southern part of the area.

During a normal Wet Season the Queensland Crossing on the Hodgson River is closed to vehicular traffic. Much of the central part of the Exploration Licence can only be reached by helicopter.

The Roper Group (Middle Proterozoic) forms resistant mesas and cuestas with a maximum elevation of 140 metres. The Vizard Formation and Balbirini Dolomite (Middle Proterozoic) produce low lying plateaux with more resistant dolomites and sandstones forming low strike ridges. Most streams drain towards the Roper River.

Vegetation is open sclerophyll forest over most of the area although thick stands of lancewood are found in the southern part on the Balbirini Dolomite plateau.

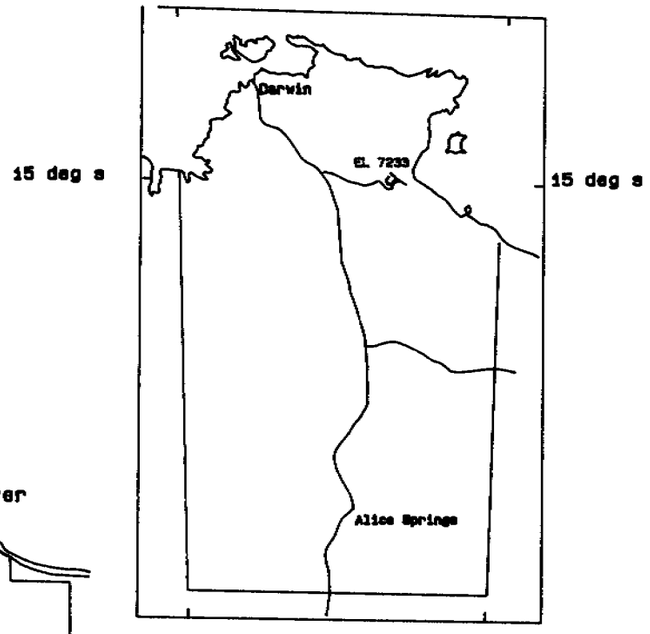
3. TENURE

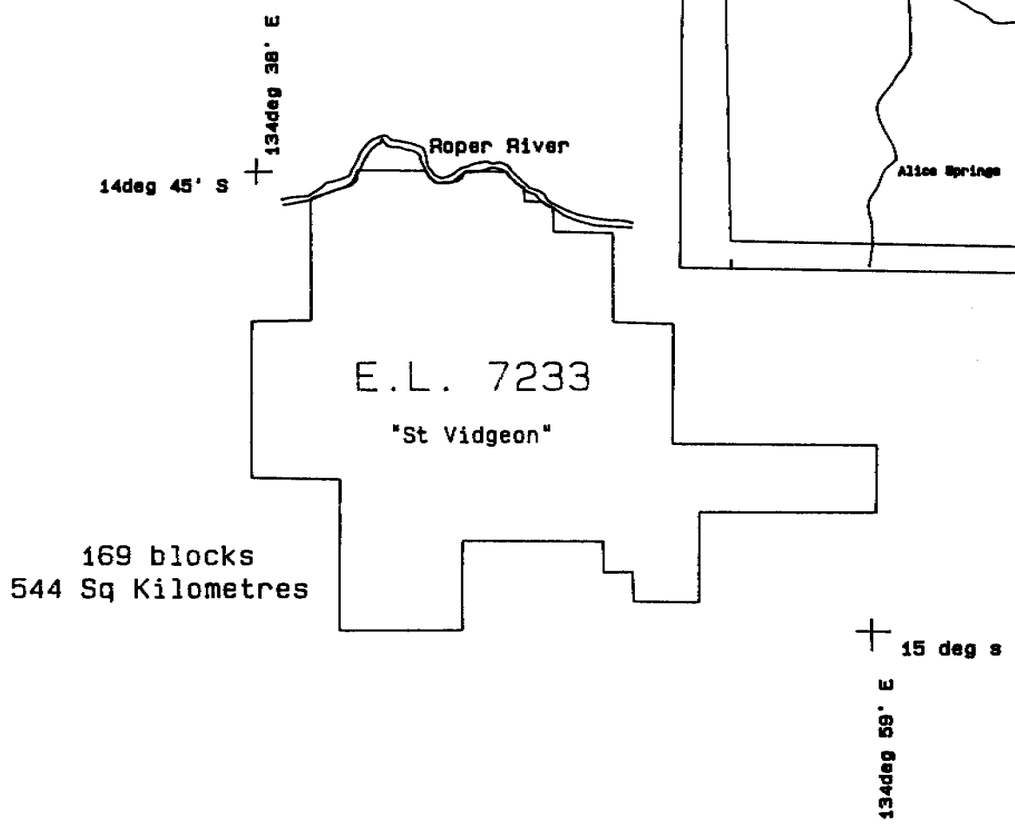
Exploration Licence No. 7233 was granted to Mount Isa Mines Limited on the 10th January 1991 for a term of six years. The Exploration Licence consists of 169 blocks with an area of 544 square kilometres. The first years expenditure commitment was set at $50 000.

Exploration was carried out by Carpentaria Exploration Company Pty. Ltd. (The name was changed to M.I.M. Exploration Pty. Ltd. on July 1st 1991).

A letter of agreement with Stockdale Prospecting Limited was signed on the 6th June 1991. This gave permission for Stockdale Prospecting Limited to carry out exploration work for diamonds within the Licence.

Locality Diagram





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E.L. 7233
"St Vidgeon"

LOCATION MAP
Figure 1

M.I.M. EXPLORATION
PTY. LTD.
NORTHERN TERRITORY

4. GEOLOGY

Most of the E.L. overlies the central part of the Urapunga Tectonic High, part of the McArthur Basin. The general structure is an anticline which is displaced by a number of north-south and northwest - southeast faults. Dips are gentle, rarely exceeding 20°.

The Vizard Formation outcrops in the core of the anticline. This formation is correlated with the McArthur Group (Jackson et al, 1987). It is about 150m thick and consists of a sequence of dolomites, quartz arenites, siltstones and shales. The carbonate content decreases up the sequence. Five units can be identified :

5. Thin bedded quartz arenites and siltstones. (top of sequence)
4. Shales with siltstone and rare chert and dolomite.
3. A very white quartz arenite.
2. Dolomite and Siltstones.
1. Dolomites often with silica replacement.

Two pink chert beds in unit 4 can be traced over wide areas. These are most likely tuffaceous.

Lying unconformably on the Vizard Formation is the Nathan Group which comprises the Smythe Sandstone Member, Balbirini Dolomite and the Yalwarra Volcanic Member.

The lowest Member is the Smythe Sandstone Member (formerly the Mt Birch Sandstone). At the base is a very distinctive boulder conglomerate bed which outcrops best on the eastern side of Nagi Hill (722 501 AMG). Above this is a very uniform quartz arenite which produces moderate relief.

The Balbirini Dolomite (formerly the Kookaburra Creek Formation) lies conformable on the Smythe Sandstone Member. This is a sequence of siliceous dolomites, sandstones and shales. It forms a low plateau over most of the western part of the E.L. which has very little drainage and a number of sinkholes. The dolomites are oolitic and stromatolitic.

The Yalwarra Volcanic Member which is interbedded with the Balbirini Dolomite consists of amygdaloidal mafic volcanics, agglomerates and minor feldspathic sandstones.

Above the Nathan group is the Roper Group. The two are separated by a major regional unconformity although this is not seen in the Exploration Licence. The Limmen Sandstone, the lowest formation in the group, produces the major relief on the margins of the area.

Along the major north-south and northwest-southeast faults linear quartz veined siliceous breccias outcrop. These are related to the Showell Fault zone and appear to post-date the Roper Group.

At the Mt Birch Prospect, Balbirini Dolomite dipping around 20° to the east appears to have been thrust into contact with the older Vizard Formation which dips around 12° to the East. The unconformity which strikes about 125° can be traced on the surface for nearly four kilometres. The unconformity is angular with younger units of the Vizard Formation coming into contact with the Balbirini Dolomite to the south. Silicification becomes very intense close to the unconformity with most sedimentary features being obliterated within thirty metres of the unconformity. Sparse malachite occurrences can be found at the surface along the unconformity while galena is restricted to two locations.

5. PREVIOUS WORK

In 1957 a helicopter survey by Enterprise Exploration Company noted the "siliceous gossans" about 4 miles south of Roper River. A mention is also made of "gold at Mt Birch, 4 miles southwest of the Roper River Mission" (Patterson, 1958).

In 1958/59 BHP held the ground under Authority to Prospect 691. They mapped and sampled the "siliceous gossans" noted by Enterprise Exploration Company. Four shallow trenches were dug to test surface copper and lead mineralisation in siliceous dolomites. One diamond drillhole was completed (MV 29DDH) in late 1959 but no significant mineralisation was intersected (Bennett,1959). This was off the northern end of what M.I.M. now calls the Mt Birch Prospect.

Geopeko held part of the area as A.P. 1436 from 1965 to 1966. They concentrated on the Yalwarra Volcanic Member's potential for base metal mineralisation. (Swarbrick 1966)

CRA held part of the area as E.L. 873 in 1973/74 looking for stratiform lead-zinc deposits. Their main target was the Kookaburra Creek Formation (now redefined as the Balbirini Dolomite). Exploration work included 1: 50 000 scale geological mapping and geochemical soil and drainage sampling. All stream sediment samples were assayed from the -80# fraction. Maximum values were 30ppm for lead and zinc in stream sediment samples and 130ppm Pb in soils.
It was concluded that these values were insignificant and the area was dropped (Polkinghorne & Rudd, 1974).

From 1978 to 1981, W.M.C. spent $161,000 exploring for stratiform Cu-Pb-Zn in E.L. 1711 which included the southern part of E.L. 7233. They carried out photogeology, soil sampling, induced polarisation surveys and percussion drilling over areas of Mt Vizard Formation. Results were very discouraging (Hancock, 1982).

In 1981, Geopeko held the area briefly as E.L. 2532 but after a literature review and the possibility of an Aboriginal Land Claim they surrendered the ground (O'Connor , 1981).

Ashton Mining Limited carried out a search for diamonds under E.L.'s 3355 and 3356. Results were negative (Ward and McCormick, 1983).

Exploration Licence No. 5751 (which covers the same area as the present tenement) was granted to Mr Lutz Frankenfeld in March 1988 on whose behalf Homestake Australia Limited carried out a BLEG (Bulk Leach Extractable Gold) sampling program designed to quickly assess the gold potential of the area. The highest result was 0.17 ppb Au. No further exploration work was completed (Orridge,1989).

6. WORK BY M.I.M. EXPLORATION PTY. LTD.

6.1 Summary of M.I.M. Exploration's work in 1991.

Exploration of the area by M.I.M. Exploration in 1991 was divided into three phases. The first was a regional helicopter supported stream sediment program. The second was a lag sampling program with associated rock chip sampling. The third phase was a detailed soil sampling survey.

One highly anomalous result of 530 ppm Pb (827518) from a stream sediment sample led to finding erratic copper and lead mineralisation over nearly 3.5km at the unconformity between the Balbirini Dolomite and the Vizard Formation to the southwest of the Mt Birch-Mt Vizard range. The northern part of this area was discovered by BHP in 1958. This area has been named the Mt Birch Prospect.

Lag sampling produced anomalous Cu and Pb results close to the unconformity. There is a strong silicification of both the Balbirini Dolomite and the Vizard Formation.

Rock chip sampling reported up to 0.73% Cu and 1.78% Pb.

Detailed soil sampling along the unconformity has outlined a number of potential drill targets over nearly 3.5km of strike length.

In June 1991 a survey by the Aboriginal Areas Protection Authority at M.I.M.'s request identified the range of hills between Mt Birch and Mt Vizard as highly significant to the local Aboriginal people. All exploration work close to this site and within the rest of the Licence was suspended from this time.

Petrological work by N.J.W. Croxford, Report No 691-808, June 1991 (see Appendix 6) reported that galena "may be altered variously to chalcocite, covellite, cerussite and malachite."

6.2 M.I.M. Exploration's work in 1992

Two visits were made to the Hodgson Downs community by M.I.M. personnel in early 1992, to discuss future exploration of the Mt Birch Prospect. Traditional guardians of the area were flown by helicopter to the Mt Birch Prospect to see if the proposed drilling would interfere with the nearby sacred sites.

An Aboriginal consultant, Mr John Moriarty of Adelaide who has some ties with this area, attended both visits to help explain the companie's intentions.

It was verbally agreed that the proposed exploration program would not interfere with sacred sites and that an access track could be constructed into the prospect from the Nathan River Road. Although this consent was given, the onset of the wet season prevented access. There also appeared to be an expectation among the local people that they were going to derive considerable benefits from the exploration work and resultant mining, even though no actual sacred site was going to be affected and the area is not Aboriginal freehold land. A further complication arose when the Northern Land Council talked to other people in the region and a different language group, who also have ties to the Mt Birch site, became involved.

Five rock chip samples from two locations which had visible galena were sent to SIROTOPE at Division of Exploration Science in Sydney for Pb Isotope Study. Three samples came from the extreme northern end of the prospect close to the BHP 1958 drillhole. The other two came from the centre of the prospect from a previously undiscovered outcrop. The report (SR 239) by Judith A. Dean is contained in Appendix 1.

The results of this work indicate large differences between Mt Birch style mineralisation and stratabound/stratiform mineralisation found in the McArthur Basin. The age of the mineralisation is most likely to be in the ≈1200 - 1300Ma range which would suggest the mineralisation is related to either the Nathan Group or maybe of Roper Group age.

8. CONCLUSIONS

1. The political and cultural problems attached to further work at the Mt Birch Prospect may be overcome with further negotiation, but this could take a lon time.

2. The lead isotope study downgades the potential for a major stratiform/ stratabound base metal deposit.

9. FUTURE WORK

1. An agreement should be made with the local Aboriginal people to allow exploration work close to the Mt Birch- Mt Vizard site.

2. A drilling program should test the mineralised zone every 500m along strike at depths between 15m to 100m.

3. If the drilling proves successful, follow up geophysics, soil sampling and more drilling will be needed to trace the mineralisation at the Mt Birch Prospect and to find other mineralisation in the area.

Mark McGeough
Geologist

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Appendix 1.

Lead Isotope Report

Sirotope

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REPORT TO MIM EXPLORATION PTY. LTD.

ON A Pb ISOTOPE STUDY OF

GALENAS FROM E.L. 7233,

ROPER RIVER DISTRICT, NORTHERN TERRITORY

SIROTOPE REPORT SR 239

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1. AIM OF STUDY

The aim of this study has been to determine the Pb isotopic compositions of galenas from E.L. 7233, Roper River district, Northern Territory and to determine if there is any potential for stratiform or stratabound mineralization at depth. The samples originate from the unconformable contact of the Balbirini Dolomite, which is part of the Middle Proterozoic Nathan Group, and the stratigraphically lower Vizard Formation, which is correlated with the McArthur Group. The mineralization is replacement-style, dominantly copper-rich and associated with strong pervasive silicification (M. McGeough, writt. comm.).

2. SAMPLES AND METHODS

Five surface samples, from two localities about 2.5 km apart, all containing visible galena in silicified dolomite were provided by Mark McGeough. Galena was handpicked, dissolved in concentrated nitric acid and Pb purified by micro-electrodeposition techniques onto Pt electrodes. Two samples were analysed in duplicate.

Lead was loaded onto single Re filaments in a mixture of silica gel and phosphoric acid. Isotope ratios were determined on a VG ISOMASS 54E solid source thermal ionization mass spectrometer run in fully automated mode. Results have been normalized to the accepted values of the international standard NBS SRM 981 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 depicted as error bars in the upper left hand corner of the accompanying diagrams. Also shown are the standard error ellipses for these data.

3. TARGET Pb ISOTOPIC SIGNATURES IN THE McATHUR BASIN

The McArthur Basin is a mildly deformed Mid-Proterozoic basin unconformably overlying the Early Proterozoic North Australian Orogenic Province. It hosts the classic stratiform Pb-Zn-Ag McArthur-type deposits, and smaller carbonate-hosted unconformity-related and Mississippi Valley-type (MVT) deposits accociated with ancient regolith and karst systems (Plumb et al., 1990).

The target for major *shale-hosted Pb-Zn-Ag mineralization in the McArthur Group* is the HYC deposit which occurs in the Barney Creek Formation. Tuffs in the Pb-Zn zone have yielded a U-Pb zircon age of 1670 Ma (Page, 1981) which has recently been slightly revised to 1640 Ma (R. Page, oral comm., 1992).

Lead isotope data for the galena/sphalerite mineralization at HYC (Gulson, 1975; Richards, 1975;

Gulson, 1985) show a high degree of homogeneity and are conformable to average crustal Pb evolution models (Fig. 1). Wallrocks of the HYC deposit with greater than about 1000 ppm Pb have the same isotopic composition as the ore (Vaasjoki et al., 1985) whilst low-Pb wallrocks are more radiogenic and define a linear trend which projects back through the orebody value, giving a Pb-Pb isochron age of 1620 ± 20 Ma. High-Pb data from *concordant smaller deposits* such as W-fold and HYC north have almost identical isotopic compositions as HYC (Fig. 1; Carr and Gulson, 1984; Gulson, 1985).

Discordant and karstic Pb-Zn deposits occur as veins and breccia fillings in the dolomite units of the *McArthur* (Reward, Coxco, Cooley, Ridge), *Nathan* (Eastern Creek) and *Mount Rigg* (Bulman) Groups (Plumb et al., 1990). These are located at or below regional unconformities and have variable and generally more radiogenic Pb isotope ratios (Figs 2 and 3). The ages of the Nathan and Mount Rigg Groups can only be constrained between the base of the Roper Group and the top of the McArthur Group. An age of 1429 ± 31 Ma for the top of the Roper Group has been determined by Rb-Sr dating of illite (Kralik, 1982). Galena and high-Pb data for Cooley III and Ridge plot off scale with $^{206}Pb/^{204}Pb$ ratios ≈ 18.2 - 18.4.

Coxco, located about 10 km southeast of HYC, exhibits two main populations (Cook's and Cox's in Richards, 1975; Walker et al., 1983); one the same as HYC and the other variable with $^{206}Pb/^{204}Pb$ ratios up to about 16.4 (Fig. 2). Eastern Creek and Bulman occur at almost identical positions within the Balbirini Dolomite and Dook Creek Formation and immediately below the unconformity at the base of the Roper Group. A single analysis from Bulman about 300 km to the northwest of HYC in the Mount Rigg Group, also has a radiogenic value (Fig. 3; **SIROTOPE** Database). Eastern Creek exhibits two isotopic populations: one homogeneous and the other, based on only a very limited dataset, more radiogenic and heterogenous (Fig. 3; Carr and Gulson, 1984). Plumb et al. (1990) draw attention to the fact that two stages of mineralization occur at Eastern Creek; one consisting of barite, galena and minor malachite in karstic cavites, and earlier galena and minor chalcopyrite in oolite beds. The Pb isotopic data are compatible with this observation, however, from descriptions provided with the Eastern Creek samples in the early 1980's it is not possible to confidently ascribe the isotopic compositions to the different mineralization styles, other than to say that mineralization in oolites is more unlikely to have the homogeneous and least radiogenic characteristics.

Other mineralization, described as *stratabound disseminated Pb-Zn* deposits (Plumb et al., 1990), such as *Barney's, Bald Hills* (Fig. 2; Richards, 1975), *Mariner and Great Scott* (Fig. 2; Carr and Gulson, 1984) and occurrences in the *Karns Dolomite* (Fig. 3; **SIROTOPE** Database) similarly have variable and more radiogenic values than the HYC target. They are located at different stratigraphic levels in the McArthur Basin and may be MVT deposits (Plumb et al., 1990).

There are also Pb isotope data for *discordant copper vein deposits* (Fig. 2; Gordon's Coppermine Creek, all low-Pb and not plotted; Johnston's prospect) occurring as fault or fracture fillings in dominantly carbonate sequences of the McArthur Basin (Plumb et al., 1990).

In summary, the characteristic Pb isotopic compositions for stratiform/stratabound base metal mineralization are homogeneity and ratios which conform to average crustal models. In the McArthur Group, the target is the HYC mineralization. It has a Pb isotope model age, based on the Stacey and Kramers model, of 1606 Ma, compared to a revised mineralization age from tuff beds in the Pb-Zn horizons of 1640 Ma. Vein-style mineralization in the McArthur Group has variable and generally more radiogenic isotopic compositions in comparison to HYC (Fig. 2).

In contrast with the McArthur Group, no economic stratiform/stratabound mineralization is known in the Nathan and Mount Rigg Groups (Fig. 3). If galena in the oolite beds at Eastern Creek is considered syn-sedimentary, then Pb isotope ratios similar to these data may be regarded as a suitable target. This least radiogenic Eastern Creek population has a $^{206}Pb/^{204}Pb$ ratio of 16.51 and yields a Pb isotope model age of 1410 Ma. If, on the basis of the differences between the model age and age of the tuffs at HYC, this is considered to be 35 Ma too young, then a mineralization age of $\approx$ 1435 Ma is indicated. As mentioned previously, age constraints of the Nathan/Mount Rigg Groups are poor and are presently being investigated by Rod Page of the BMR.

4. RESULTS OF GALENAS FROM THIS STUDY

Lead isotope results are presented in Table 1, and in Figure 3 with reference to the average crustal Pb evolution curve, or growth curve, of Cumming and Richards (1975), the HYC target and data from the Nathan and Mount Rigg Groups.

Galenas from this study fall within two groups. Duplicate galenas from **QP 098694 and QP 098696** which are from the same area show minor variation which can be attributed to analytical error ("fractionation trend" Fig. 3; Appendix). They plot well above the growth curve on the $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram, indicating a high source U/Pb ratio compared to average crustal rocks. Galenas from the other locality have slightly higher $^{206}Pb/^{204}Pb$ and lower $^{207}Pb/^{204}Pb$ ratios.

The Roper River galena Pb isotope data are considerably more radiogenic than the HYC deposit, or any of the data from deposits in the Nathan and Mount Rigg Groups.

5. INTERPRETATION

The highly radiogenic nature of the Roper River galenas compared to what may be expected for stratiform/stratabound mineralization in the Nathan Group suggests that this mineralization is either epigenetic and derived from high U/Pb source rocks, or has resulted from the mixing of fuilds from two or more sources. Stacey and Kramers (1975) model ages for Roper River range from $\approx$ 1200 - 1300 Ma; however little significance can be placed on model ages for mineralization which has

resulted from mixing of Pb from two or more sources. In addition, the five samples although originating from two localites about 2.5 km apart, are relatively inhomogeneous, displaying a 2σ range in $^{206}Pb/^{204}Pb$ ratio of 0.85% compared to 0.11% for HYC. The potential for MVT style mineralization is also considered low based on these Pb isotope data since examples in the McArthur Basin, such as Coxco, have similar or slightly more radiogenic ratios to HYC.

The large differences between Roper River and Eastern Creek also do not support these data indicating replacement-style mineralization from a stratabound/stratiform deposit at depth. If mixing were to have taken place between a major Pb-Zn accumulation and some other fluids during remobilization, then isotopic compositions closer to Eastern Creek would have been expected as, for example, has been found in vein-style mineralization near HYC (Gulson, 1975; Richards, 1975).

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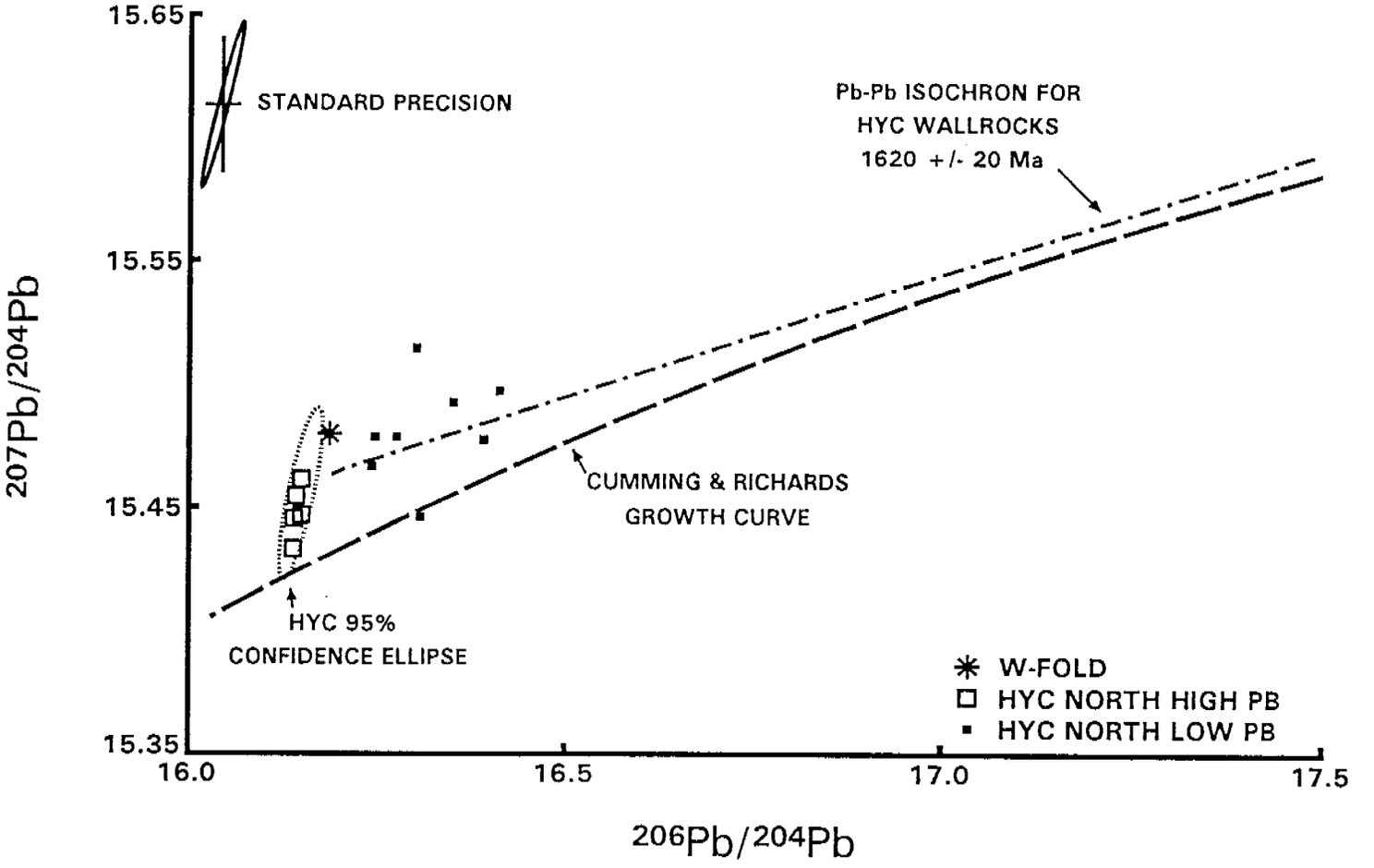
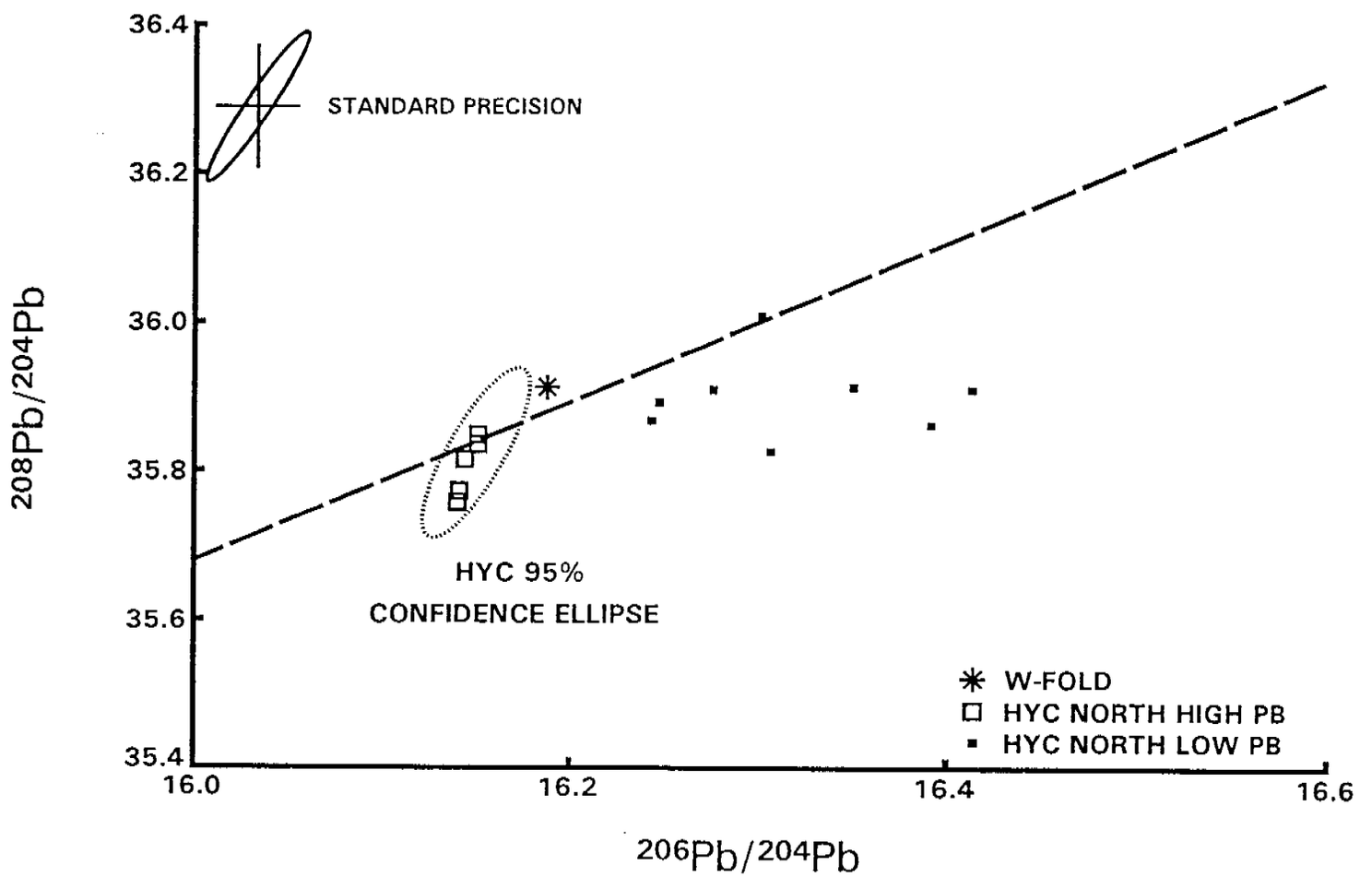
TABLE 1. LEAD ISOTOPE DATA FOR GALENAS FROM M.I.M. EXPLORATION'S ROPER RIVER E.L. 7233, NORTHERN TERRITORY

	Sample	$\frac{^{208}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{206}Pb}{^{204}Pb}$	$\frac{^{207}Pb}{^{204}Pb}$	$\frac{^{208}Pb}{^{204}Pb}$
1	QP 098693	2.1559	0.9156	17.000	15.566	36.650
2	QP 098694	2.1692	0.9240	16.887	15.603	36.631
3	QP 098694 R	2.1684	0.9240	16.876	15.593	36.593
4	QP 098695	2.1581	0.9166	17.008	15.589	36.705
5	QP 098696	2.1682	0.9238	16.875	15.588	36.589
6	QP 098696 R	2.1685	0.9237	16.891	15.603	36.628
7	QP 098697	2.1535	0.9138	17.037	15.569	36.689

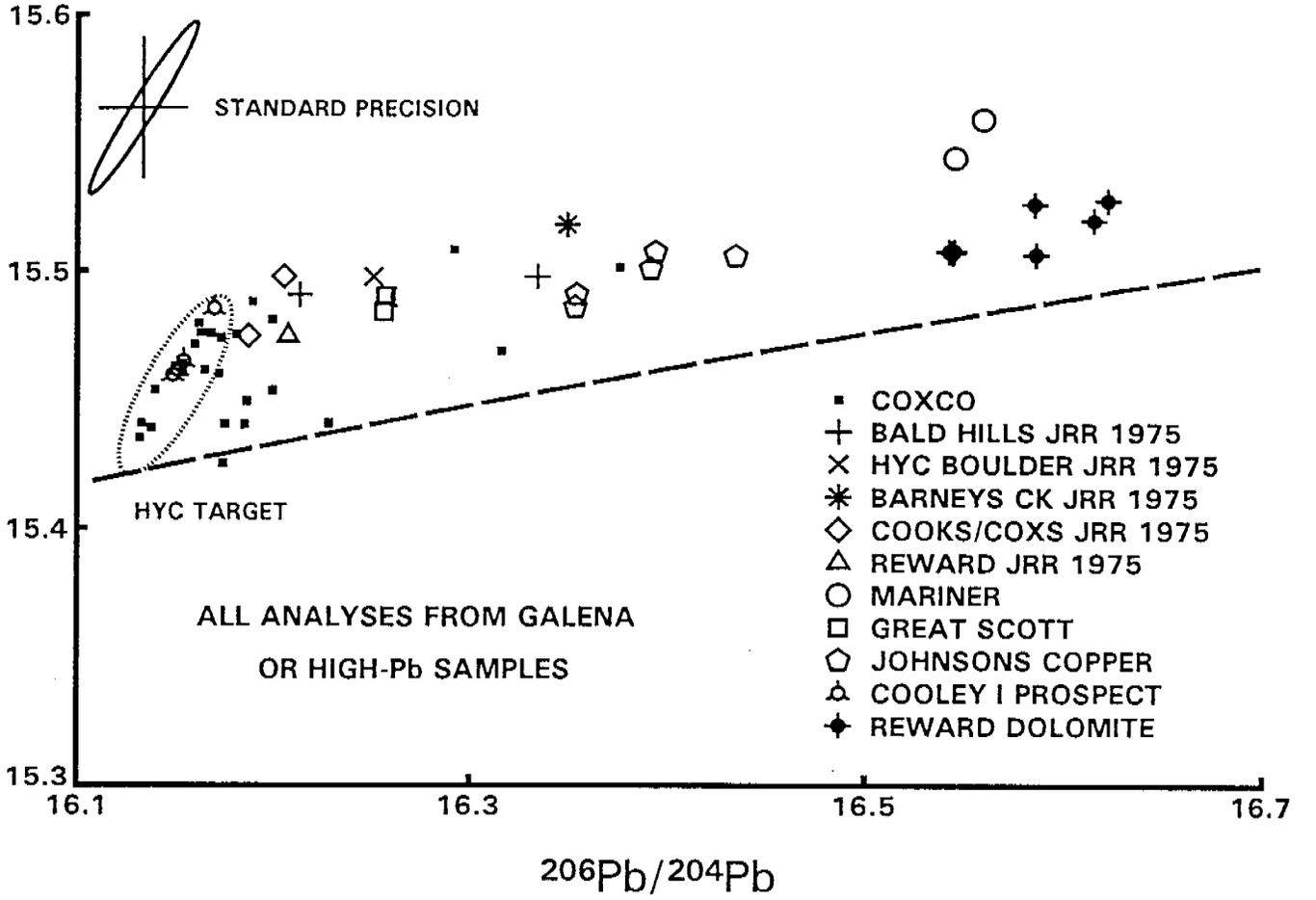
R denotes repeat sampling and analysis
All samples galenas
SAMPLE NUMBER PREFIXES REFER TO PLOTTED POINTS FIGURE 3

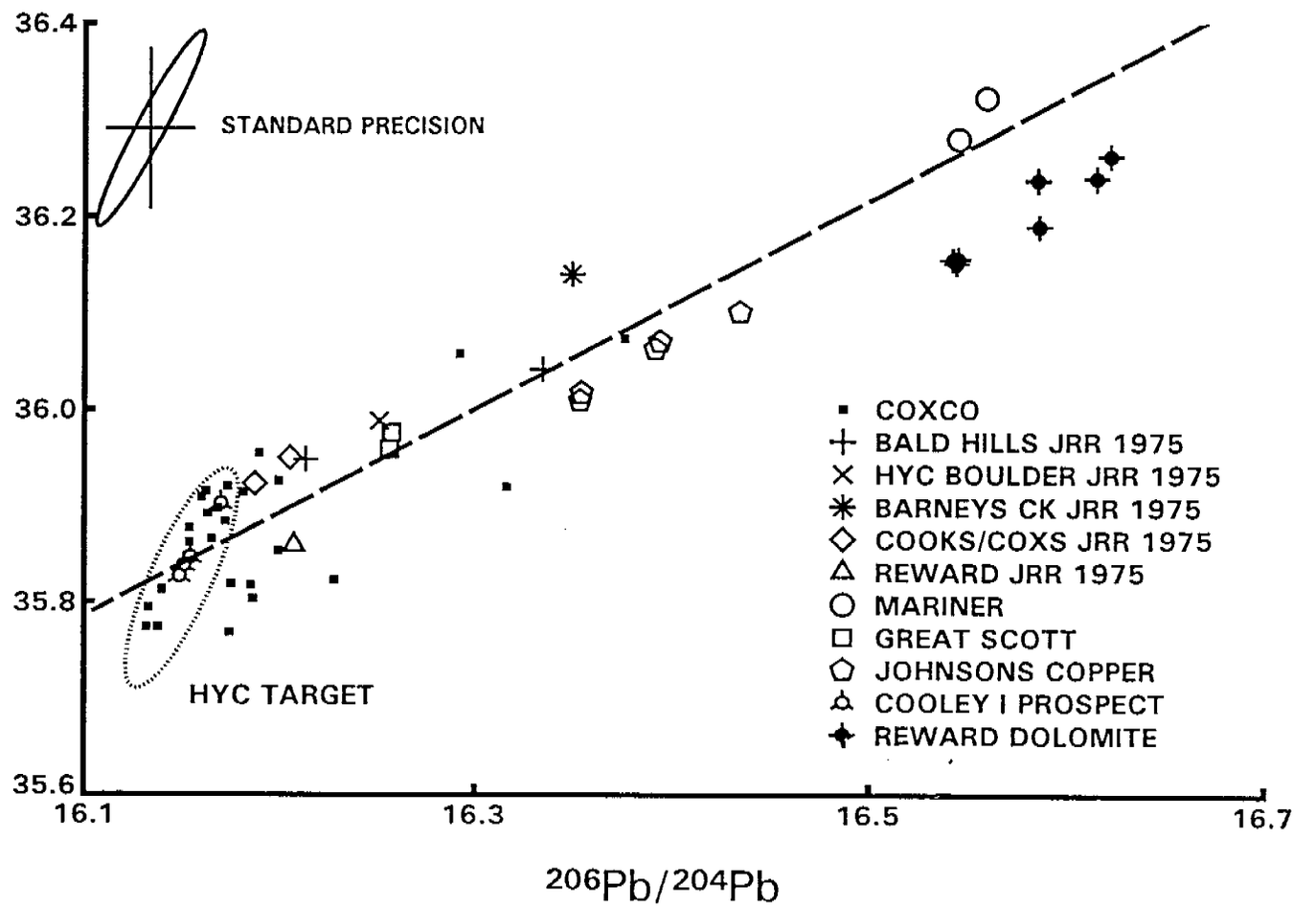
STRATIFORM MINZ McARTHUR GROUP



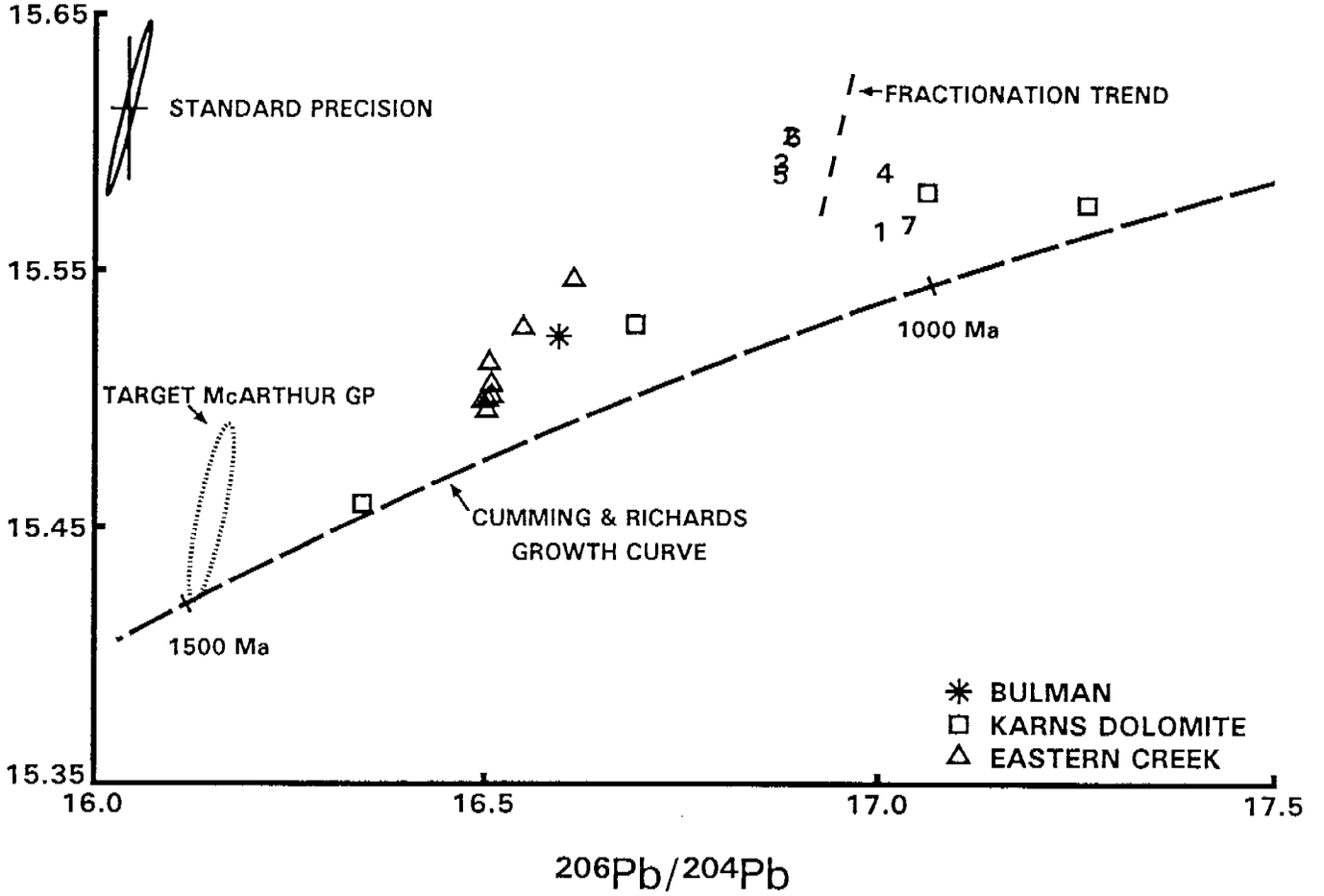


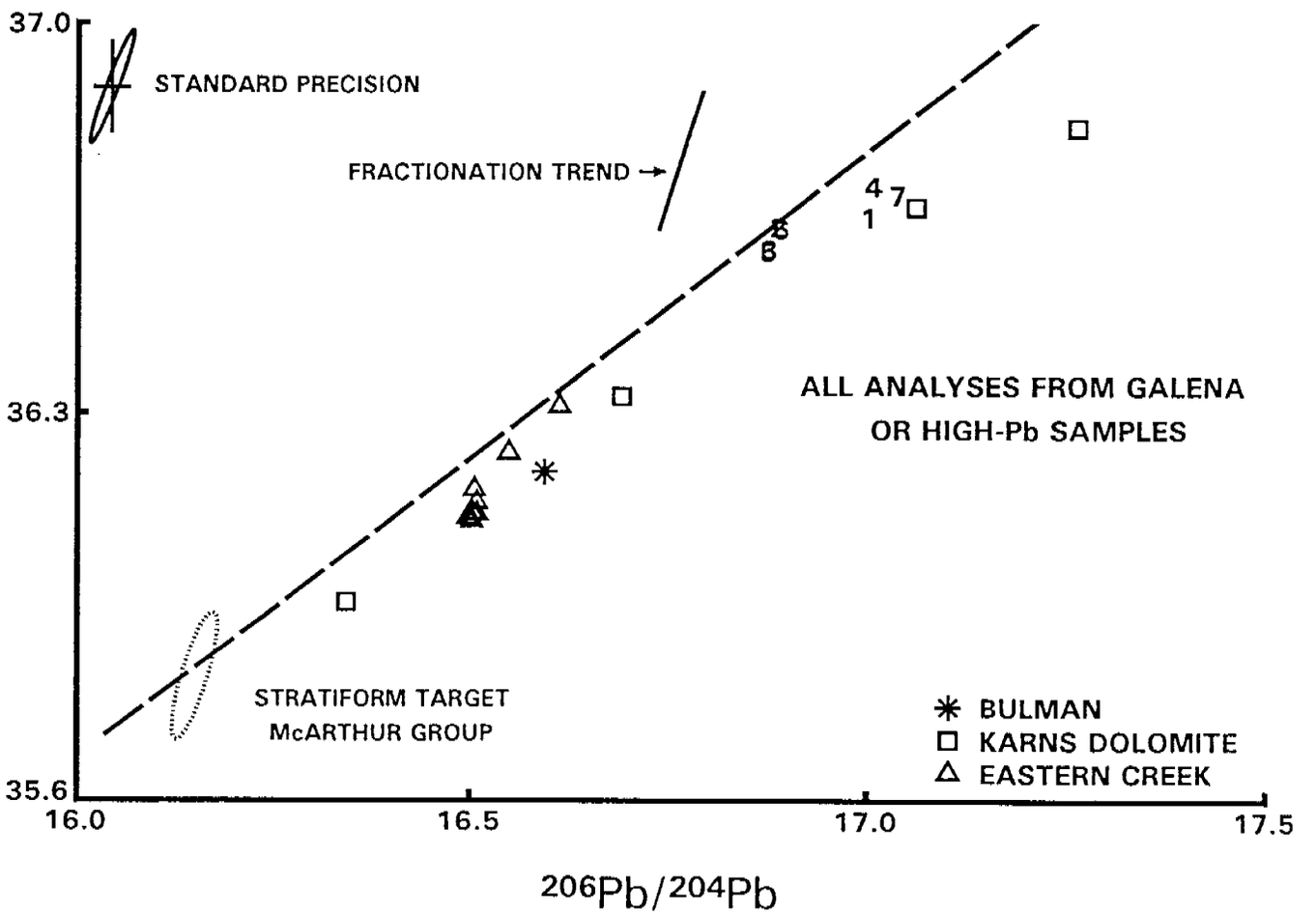
OTHER MINZ McARTHUR GROUP





MINZ ROPER & NATHAN GROUPS





APPENDIX 1 - BRIEF DISCUSSION OF Pb ISOTOPE SYSTEMATICS AND TERMINOLOGY

Lead isotope data are conventionally represented as the ratio of one isotope of Pb to another, most often in terms of $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$. Whilst ^{206}Pb, ^{207}Pb and ^{208}Pb derive from the constant radiogenic decay of ^{238}U, ^{235}U and ^{232}Th respectively, ^{204}Pb has no parent isotope and so its abundance does not change through geological time. Thus the three ratios above are continually increasing with time according to well defined decay criteria. Lead isotope ratios are presented graphically on conventional XY ratio plots; $^{208}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram details the Th-U/Pb system, and the $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram the U/Pb system.

Variation of Pb isotope data results principally from geological factors. However, some variation can be ascribed to **analytical errors**. The 95% confidence ellipse of the error associated with any Pb isotopic analysis is shown in the top left hand corner of each diagram. The major axis of this ellipse indicates the strong correlation inherent in the errors which arise from **fractionation** and to a lesser extent **^{204}Pb** error. Fractionation occurs at the very high temperatures induced during mass spectrometer analysis and results from preferential emission of the light isotopes (e.g. ^{204}Pb) relative to the heavier isotopes (e.g. ^{208}Pb, ^{207}Pb). ^{204}Pb error results from the lower precision in estimating peak heights of this low abundance isotope.

The geological variables are:

1) The **age** of the sample, i.e. the time at which the Pb was incorporated into the rock/mineral.

2) The relative amounts of Pb, U and Th (expressed generally as $^{238}U/^{204}Pb$ (μ) and $^{232}Th/^{204}Pb$) in the source rocks from which the Pb was leached prior to incorporation in the rock/mineral.

3) The U/Pb and Th/U ratios in the rock/mineral between the time the Pb was incorporated and the present.

A **growth curve** is a model of this variation and indicates the expected isotopic composition of Pb-rich ores at any particular stage in the Earth's history. There is no unique growth curve for the Earth, and different curves can be generated assuming source rocks with different U/Pb and Th/U ratios. **Model ages** can be determined when data from high-Pb samples plot on or near a growth curve on a $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram. The accuracy of model ages vary considerably and relies on the appropriateness of the chosen model. The commonly used Cumming and Richards curve is based on the assumption that the U/Pb and Th/Pb ratios in the Earth's crust have been varying continuously and is correlated with the known ages of a set of massive sulfide deposits which probably gained their Pb from hydrothermal solutions which leached large volumes of rocks through the crust. Massive sulfides and other ores which leached their Pb from mantle rocks or lower crustal rocks will not fall on this growth curve.

The Pb isotope **fingerprinting technique** is based on the fact that in any geological domain, ores forming during a particular mineralizing event from the same or similar source rocks will have the same isotopic composition. In some cases we can broadly predict the likely isotopic composition based on geological criteria such as age/rock type etc., but in general the technique relies on a library of data on known ore deposits in a region.

This isotopic "fingerprint" represents the Pb isotopic composition at the time of formation of the ore/rock - otherwise known as the **initial ratios**. If the ore/rock has relatively low U/Pb, and Th/Pb ratios, such as in galena, then these initial ratios will not change with time because insignificant ^{206}Pb, ^{207}Pb and ^{208}Pb will have been added *in situ* since the time of formation by the radioactive decay of ^{238}U, ^{235}U and and ^{232}Th respectively. However with "low-Pb" samples (generally less the about 50-100 ppm for Palaeozoic samples and less than about 500-1000 ppm for Proterozoic samples) measurable ^{206}Pb, ^{207}Pb and ^{208}Pb will have been added by *in situ* radioactive decay and so the $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios will increase; i.e. will be **more radiogenic**. This effect will be magnified in high-U samples and higher Pb contents than the figures quoted above are needed to guarantee that significant additional radiogenic Pb has not changed the initial ratios.

Where *in situ* radioactive decay has occurred the ratios will plot on a line on any of the diagrams commonly presented. This line will always incorporate the initial ratios. On the $^{208}Pb/^{204}$ vs $^{206}Pb/^{204}Pb$ diagram the slope of the line is dependant on the Th/U ratio of the sample, whereas on the $^{207}Pb/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagram the slope is dependant only on the time interval over which radioactive decay has taken place. In this latter case, where it can be shown that the isotope ratios of all the points on such a line have developed under a closed system with respect to Pb and U then the line is termed an Pb-Pb **isochron**. An isochron is thus defined by the slope, **m**, of a linear regression through the data. An estimate of how well such a regression fit the data is gained from Mean Square Root of the Deviates or **MSWD**. This function compares the deviation of each point from the regression relative to the estimeat of analytical precision. An MSWD of 1 or less indicates that the data deviate minimally from the regression whereas higher values indicate increasing deviation.

Source rock studies involve determining, if possible, the initial Pb isotope ratios of those rocks considered to be possible source of metals for mineralization. Such studies are particularly important in areas where mineralization may result from a syngenetic event, such as a VMS deposit, or from later granite intrusion. The syngenetic signature may be well established, but it is also important to know what is the likely Pb isotopic composition of epigenetic mineralization forming in response to the intrusion. This may be done by measuring mineralization known to be associated with the intrusion, such as skarns, or by determining the Pb isotopic composition of a relatively high-Pb silicate component such as K-feldspar. Although K-feldspars may contain a significant proportion of radiogenic Pb (i.e. Pb derived from *in situ* radiogenic decay since crystallization) techniques are available that enable, in many instances, the discrimination of the initial component from the radiogenic component.