APPENDIX A

ACKNOWLEDGEMENT OF CONTRIBUTIONS

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Contributions to this published work consist of:

M. D. Raine	Initial research and text including the following contribution: 100% (p. 3-13), 10% (p. 16-20), 100% (p. 21-23), 80% (p. 25) and 100% (p. 26-27)
S. C. Dominy	Normal supervisory contributions and text including the following contribution: 90% (p. 16-20), 100% (p. 24) and 20% (p. 25)
G. F. Johansen and J. K. Bartlett	Figures 1-9, access to Bendigo Mining Ltd. sampling data and mine development

A number of minor grammatical alterations have been made to the text since its publication in 2003.

CHALLENGES OF SAMPLING EXTREME NUGGET-EFFECT GOLD-QUARTZ REEFS AT THE NEW BENDIGO PROJECT, CENTRAL VICTORIA, AUSTRALIA

Abstract

The Bendigo Goldfield is located in the state of Victoria, Australia, and is one of a number of fields that constitute the central Victorian goldfields. Since 1993, Bendigo Mining Ltd. has been carrying out an extensive re-evaluation of the goldfield and is currently well advanced in developing an underground mine. The turbidite hosted auriferous quartz reefs are structurally complex and spatially related to anticlinal hinge zones and reverse faults. The gold within the quartz reefs is characterised by both its coarse nature (100 up to >5000 µm) and erratic distribution, as a result the goldfield has been deemed an extreme nugget effect system. This characteristic is indicative of mineralisation that is especially challenging to sample and evaluate. A point emphasised by the fact that diamond drilling has been a good measure of structural and geological continuity, but a poor measure of grade and grade continuity. Drilling combined with on-reef development, bulk sampling and detailed geological studies are required for resource evaluation. For grade control a balance must be sought between sample representivity, cost, turn around time and practicality. To date it has been necessary to use bulk samples in order to maintain sample representivity, however, the cost and turn around time are significant. Consequently, a micro-bulk sampling system has been introduced which attempts to overcome these problems by providing a fast, practical method that can define ore from waste. Bulk sampling and on-reef development remain necessary for the estimation of resources and reserves.

Key words: Bendigo Goldfield, central Victorian goldfields, sampling protocols, coarse gold.

INTRODUCTION

Gold-bearing quartz reefs commonly exhibit erratic and unpredictable grade distributions, particularly with the occurrence of coarse gold (>100 µm). The application of variography to sample data from this type of deposit frequently reveals that the mineralisation is characterised by a high to extreme nugget effect. Economic grades are typically contained within discrete ore shoots and specific phases of mineralisation. The presence of coarse gold combined with an erratic gold distribution makes sampling and assaying, and therefore resource estimation especially difficult (Annels, 1991; Dominy *et al.*, 2000; 2001b; 2003c). A strong understanding of the geology, particularly grade distribution and its underlying controls, is imperative when attempting to optimise sampling and resource estimation protocols (e.g. Dominy *et al.*, 2003c).

This contribution describes the progressive development and optimisation of sampling protocols as part of the New Bendigo Project. The problems and challenges encountered, and the potential solutions are documented. The fundamental importance of integrating geological understanding in to sampling programs is emphasised. Preliminary observations on the occurrence of gold and its distribution within the Bendigo Goldfield are presented.

THE NUGGET EFFECT

What causes an extreme nugget effect?

Many gold deposits are characterised by a high to extreme nugget effect. 'Nugget effect' is a geostatistical term and "a measure of the importance of the random factor in an orebody" (Annels, 1991). The nugget effect has two components; the first is geology related and the second, sampling related. The geological component results from an erratic gold distribution and/or significant variations in gold grain size. On a global scale, an erratic grade distribution is caused by the occurrence of localised high-grade zones within a background of low-grade to barren mineralisation/host rock. On a local scale, an erratic grade distribution is directly related to the influence of individual gold grains, whereby grade variations result from varying grain size and the clustering of individual grains. Recent work by Platten & Dominy (2003) has shown that gold veins can display rapid and erratic variations in the texture that controls gold deposition and hence the geological nugget effect.

The sampling component of the nugget effect is the consequence of sampling errors, and is particularly problematic when dealing with coarse gold bearing mineralisation. The causes of sampling errors and the methods of quantifying and mitigating such errors are well documented (e.g. Gy, 1982; Francois-Bongarcon, 1999).

The influence of an extreme nugget effect on sampling

Mineralisation like that found at Bendigo, which is characterised by an extreme nugget effect, presents the most difficult and challenging to sample and evaluate successfully (Dominy *et al*., 2000; 2001a, b; 2003c). An extreme nugget effect inevitably means that assay values will possess a large statistical range, regardless of how closely spaced the samples are taken, and regardless of whether they are splits from the same sample. As a result, the unpredictability associated with an extreme nugget effect makes it very difficult to evaluate unsampled ground, therefore increasing the potential error in any resource estimate. Pure nugget effect results from a truly random grade distribution, which implies that the data are independent and that all estimation methods would be relatively ineffectual in predicting the grade of unsampled locations (Annels, 1991; Dominy & Annels, 2001).

During exploration and evaluation, avoiding the large variations associated with an extreme nugget effect improves exploration success and makes resource evaluation more representative and reliable. Therefore, understanding and managing the nugget effect has significant economic importance (Dominy *et al.*, 2003b). A detailed knowledge of the geological controls on, geological continuity of, and grade continuity within, gold bearing phases is crucial in understanding, and managing the impact of a high to extreme nugget effect. Optimisation of sampling protocols along with rigorous quality controls during sample preparation and analysis are also essential.

NEW BENDIGO GOLD PROJECT

History and background

The Bendigo Goldfield is located in the state of Victoria, Australia, and is one of a number of fields that constitute the Central Victorian Goldfields. The Bendigo Goldfield is the second largest producing goldfield in Australia (after Kalgoorlie's Golden Mile) with a total historic production of 22 Moz (Wilkinson 1988a, Johansen 1998; 2001a, b). Alluvial gold was discovered in 1851 with hard-rock mining commencing in 1854. The last operating underground mine, the Central Deborah, closed in 1954.

Geology and mineralisation

The Bendigo Goldfield is a classic slate-belt style of mineralisation hosted by 10-50 m thick, upward-fining turbidite cycles (Turnbull & McDermott, 1998). The turbidite hosted auriferous quartz reefs are structurally complex and spatially related to anticlinal hinge zones and reverse faults (e.g. Cox *et al.*, 1991a; Schaubs & Wilson, 2002). The geological model applied by BML (see Johansen, 2001b) to explain the development and distribution of quartz reefs at Bendigo envisages that a regionally extensive period of ~E-W shortening resulted in the initiation, amplification and tightening of folds with chevron geometry. The continuation of ~E-W shortening after fold lockup resulted in the development of reverse faults and the rupturing of fold hinges at regular vertical intervals. The resultant structures became the focus for quartz dominated, auriferous mineralisation and the formation of auriferous reefs with various morphologies, on or in close proximity to the anticlinal axes and at vertical intervals of between 150-250 m. These structural and mineralised zones, which have along-strike extents of many kilometres, are termed ‘ribbons’. The regular repetition of ribbons with depth was historically, a well-known feature of the goldfield.

Individual quartz reefs occur in a variety of structural settings and can display complex cross-sectional geometries. Mineralisation is dominantly fault controlled, in many cases fold geometry or bedding attitude has clearly influenced fault geometry (Cox *et al.,* 1991a). Johansen (2001b) and Fraser & Quigley (2003) recognise five broad categories of reef, which encompass the vein geometries present at Bendigo, these are: 1) saddle and leg reefs; 2) false saddle and neck reefs; 3) fault reefs; 4) spur reefs; and 5) cross-course reefs. Detailed discussions of the mineralised structures observed at Bendigo are given by Dunn, (1896); Whitelaw, (1914); Stone, (1937); Chace, (1949); Mckinstry & Ohle, (1949); Thomas, (1953a, b); Sharpe & MacGeehan, (1990); Cox *et al*., (1991a); Willman & Wilkinson, (1992); Jessell *et al*., (1994); Ramsey et al., (1998); Sibson & Scott (1998); Turnbull & McDermott, (1998); Jia *et al*., (2000) and Schaubs & Wilson, (2002).

Nature of gold and its distribution

Occurrence of gold

Coarse gold particles are exclusively associated with quartz veining occurring:

1. On pressure solution features, e.g. stylolites and slickolites;
2. On vein-wall rock contacts, particularly shale-quartz contacts;
3. As free gold;
4. In association with sulphides; and
5. In association with wall rock fragments or laminations.

Gold also occurs in association with sulphides in wall rock immediately adjacent to quartz veins (Johansen, 2001b).

Gold grades

In general, the gross reef structures found at Bendigo contain low-grades in the range of 0.3 to 1.5 g/t Au with higher-grade areas of more than 8 g/t Au. High-grade ore shoots can carry grades as high as 95 g/t Au (Thomas, 1953b). Individual structures may carry grades in the order of 100's of g/t Au, however, gold-bearing veins/phases appear to be narrow and therefore grades are susceptible to heavy dilution when considering minimum mining widths. Historical production grades for the entire goldfield averaged between 10-15 g/t Au. The investigation of historical stoping patterns and bulk-sampling data indicate that the grade, though erratic in a local sense, tends to be more gradational on a goldfield-scale (Johansen, 2001b).

Gold particle size

Gold occurrences at Bendigo are characterised by their coarse nature and erratic distribution. Bendigo differs from the majority of other gold deposits because the grade of mineralisation is predominantly a function of gold particle size rather than the number of particles present (Johansen, 2001b). Coarse gold typically ranges in size from 100 up to 5000 μm; however, when high grades are encountered gold particles commonly exceed 5000 μm.

A theoretical range for gold particle size has been developed for Bendigo and is based on four size intervals (Johansen, 2001b), these are:

1. Fine gold - probably less than 30 μm and nearly always present in a mineralised zone. It may be responsible for the background grades of 0.2 g/t Au. Gold particles are erratically distributed, but present no severe sampling problems.
2. Coarse gold I - averaging 100 μm, generally just visible with the naked eye. The grains are erratically distributed and probably contribute further to the background grades up to 0.5 g/t Au. The coarse grains cause some problems during pulverisation; though individually have only a small effect on the assay grade.

3. Coarse gold II - averaging 800 μm and easily visible with the naked eye. This third type of gold is probably responsible for an increase in the in-situ grade from 0.5 to 2 g/t Au. The coarse grains cause some problems during pulverization. There is not a large percentage of gold present at this particle size.
4. Very coarse gold – a grain size of greater than 3000 μm occurs once the grade exceeds 2 g/t Au. At high-grades, much of this gold will be greater than 5000 μm in size. It is extremely coarse and erratically distributed and will occasionally report to drill core samples. Pulverizing these samples has little effect on the coarse gold particles, resulting in an extremely heterogeneous sample. The particles are more likely to appear in a 2 kg screen fire assay, as it is 40 times as large. Coarse particles of this size will probably screen fire assay in the 50 to 10 000 g/t Au range.

Gold grade and geological continuity

Raine *et al*. (2003) and Dominy *et al*. (2003b) report preliminary work that recognises four geological and grade domains within the St. Anthony Reef, D3 Reef, and Upper S3 Reef:

1. Reef domain – predominantly gold-poor (0.1–1.0 g/t Au) and continuous for 100's up to 1000's of metres. On a local scale deformation and faulting has influenced the geometry of and/or alter the geometry of reef domains.
2. Ore shoot domain – predominantly medium to high grade (up to 30 g/t Au) and continuous for 10's of metres. On a local scale ore shoot domains are greatly influenced by the presence of high-grade single veins.
3. Single structure domain – a single structure domain may consist of one or more phases of mineral growth, whereas reef and ore shoot domains are comprised of one or more single structures. Single structure domains generally display poor continuity (<10 m), however, laminated veins can display good continuity on a scale of 100's of metres. Single structures can carry grades in excess of 900 g/t Au.
4. Paragenetic domain – single phases of mineral growth or modification, of which some have associated gold.

Gold-bearing single structure domains are characterised by large variations in gold grade. Such variations in grade occur either within a single structure domain or between single structure domains within the same reef domain. The grade of an auriferous paragenetic domain is directly related to the influence of individual gold grains, whereby high-grades result from an increase in grain size and/or the clustering of individual grains. The grade distribution observed within a single structure domain is therefore related to the presence of, continuity of and amount of gold contained within the gold-bearing phase(s).

Early observations indicate a link between the geometry of pressure solution features (e.g. stylolites) and the localisation of gold, gold grain size and gold distribution. It has also been noted, that in several instances where significant amounts of gold occur on quartz–shale contacts, the contacts themselves are stylolitic in nature. These observations suggest that pressure solution structures play a key role in the localisation of gold.

Mining operation

In 1993 BML acquired a number of tenements from Western Mining Corporation Ltd. (WMC). These tenements combined with the leases already held by BML resulted in the company being the first to gain control of the entire goldfield. A goldfield, which historically had supported more than 1300 individual companies and been subdivided into thousands of mining leases (Johansen, 2001b).

Since 1993, BML has been involved in an extensive re-evaluation of the goldfield and is currently in the process of developing an underground mine. Initial targets and the focus of current development lie on the Sheepshead and Deborah anticlines. Resources and reserves defined to date are given in Table 1.

***Table 1. New** Bendigo Gold Project **- resource** and reserve estimate as of July 2003 for the D3, D4 and S3 ribbons. Source: BML.*

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* Probable Ore Reserve derived from Indicated Mineral Resource.

SAMPLING THE NEW BENDIGO GOLDFIELD

Sampling forms the basis for all mineral resource estimation and grade control programmes. The requirement for high quality samples has been long recognised, as deficient sampling will affect subsequent grade estimates, with errors compounding through the process. Quality control in sampling is of critical importance and nowhere more so than in the coarse gold-bearing environment (Dominiy ***et** al.*, 2000). The Bendigo Goldfield is one of the world's classic coarse gold bearing, extreme nugget-effect systems and poses particular problems.

The development of sampling protocols

Historically at Bendigo, the main forms of grade control were the visual calling of grade through the presence of visible gold, bulk sampling of 20t or more, and the careful monitoring of production as a form of continuous bulk sampling. Assaying techniques, which utilise small charge weights, though available, were not used as the workers recognised the problems of using small sample sizes in a coarse gold environment (Johansen, 2001b).

WMC (1979-1989) was the first company to undertake significant percussion, reverse circulation and diamond drilling within the Bendigo Goldfield (Johansen, 1997; 2001b). Sample assaying was initially carried out using 25g assay charges with aqua regia digestion and an atomic absorption spectroscopy (AAS) finish. Erratic grades were observed, which for this type of deposit was to be expected especially considering the small sample and assay charge sizes. In an attempt to overcome this Fire Assay (FA) was trailed using larger assay charges of 50, 100 and 250g. Results still showed substantial variability and poor repeatability even with the larger charge sizes.

Figure 1 clearly shows that sampling and assaying of gold mineralisation present at Bendigo is challenging. The Fosterville mine, 20 km to the east of Bendigo is characterised by fine gold that occurs in association with disseminated arsenopyrite. Sample assays display a high degree of repeatability as shown by Figure 1. In contrast to this the Bendigo data displays a shotgun pattern, which is the result of extremely poor repeatability among assays from the same sample pulps (Cahill, 1994; Fletcher, 1996; Johansen, 1997; Dominy *et al.,* 2000).

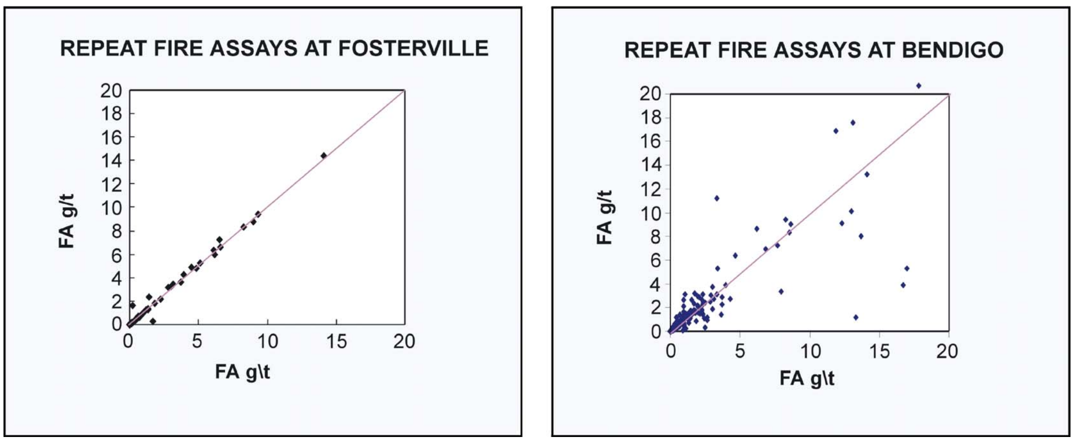


Figure 1. *Comparison of repeat fire assay data at Bendigo and Fosterville. All samples prepared in an LM5 pulveriser to nominal -75 micron with 2 samples taken from each pulp.*

In light of this information, initial work carried out by BML focused on determining and validating the most cost effective assaying technique. The results from this study are presented in Fletcher (1996), Johansen (1997; 2001b) and Dominy *et al.* (2000). The following conclusions were made:

1. Extremely poor reproducibility of fire assay data from the same sample pulp;
2. Extremely poor reproducibility of assay data from different splits of the same sample, irrespective of the assay charge size; and
3. A consistent increase in the overall grade with increased assay charge size, but only when a large number of samples are considered.

As part of this study BML compared fire assays with screen fire assays (SFA) and 3kg cyanide leach (BLEG) assays (Figures 2 & 3). In both cases the smaller 100g fire assays understated the larger SFA and BLEG assays. After careful analysis of the data and a thorough review of assay and sample preparation procedures Fletcher (1996) and Johansen (1997) concluded that:

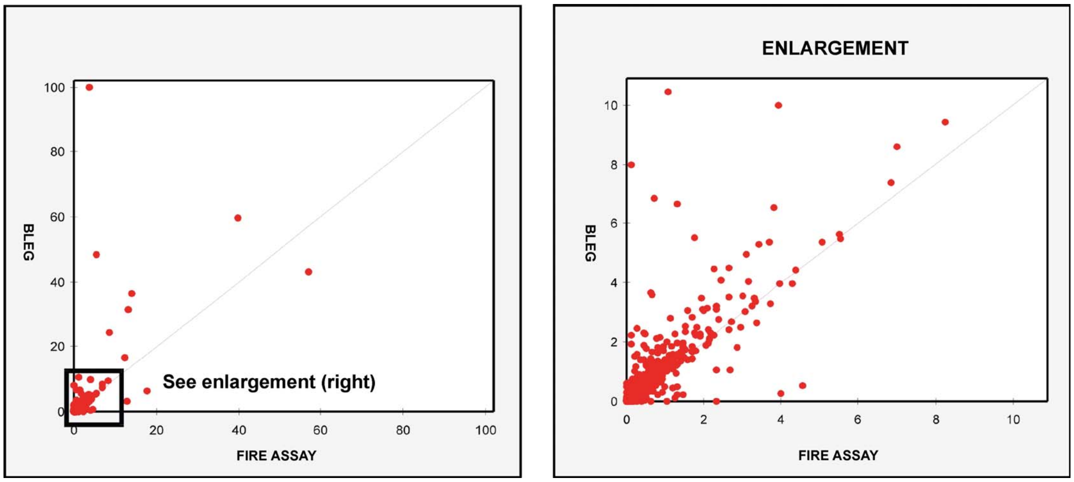
1. The lack of correlation between splits of a single drill sample was a function of an erratic gold distribution and was not a function of poor sampling methodology; and
2. The consistent increase in overall grade with a larger assay charge for a large number of samples was a function of laboratory sample preparation procedures.

It is true that significant errors maybe incurred during sample preparation when dealing with coarse gold bearing mineralisation. However, the nature of the mineralisation and the sampling protocols, particularly in this case, sample and assay charge size, will also greatly influence any errors incurred and the variability, reproducibility and representivity of assays.

Though a change from fire assay to SFA or BLEG assay helped to reduce the problems associated with sample preparation, the larger sample size did not overcome the inherent problems of sampling and assaying in a coarse gold environment. As is shown by Figures 4 & 5, the repeatability between separate splits from the same drill samples remains poor.

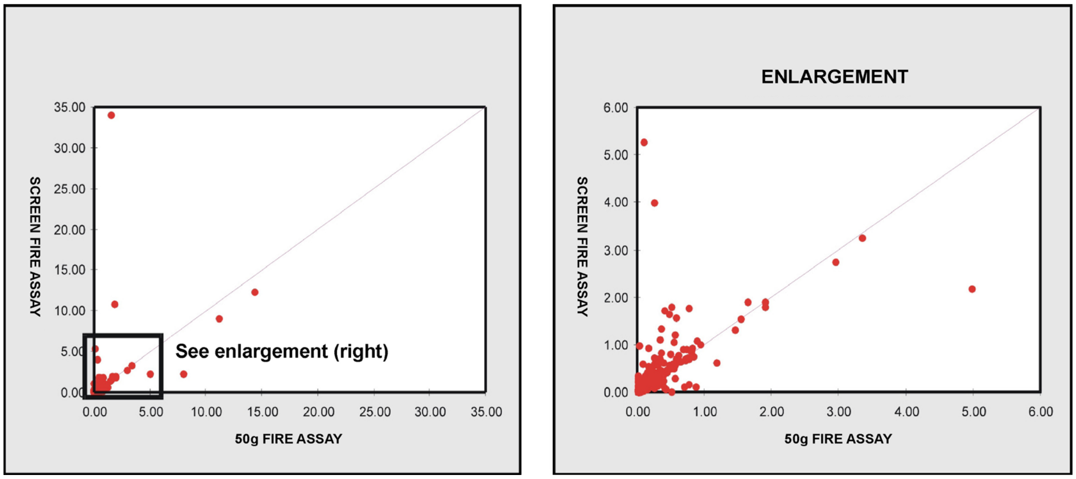
Following the review of assay procedures a re-evaluation of BML drill hole sampling and splitting methods was conducted both internally and in conjunction with industry consultants. This audit provided confidence in sampling and assaying procedures and the interpretation of results. However, the findings showed that it would not be possible to accurately define grade from drilling alone. It was clear that additional grade data from trial mining and bulk sampling of underground targets would remain necessary. Initial on-reef development carried out by BML had three principal objectives:

1. To gain access to the reefs allowing detailed geological studies to be carried out;
2. To allow mining conditions to be accessed; and
3. To allow detailed sampling studies to be carried out, in particular, the initiation of a bulk sampling and trial mining program.



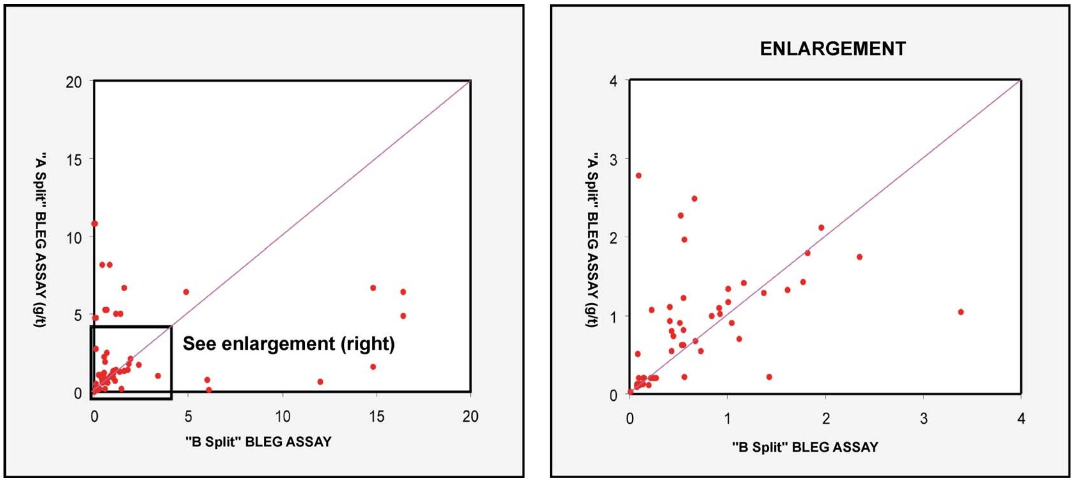
RANGE (g/t Au)	FA (Mean)	BLEG (Mean)	NO. OF SAMPLES	% UNDERSTATE
FA<0.1	0.04	0.06	267	33
0.1<FA<0.2	0.15	0.26	130	42
0.2<FA<0.3	0.25	0.32	95	22
0.3<FA<0.5	0.4	0.45	123	11
0.5<FA<1.0	0.71	0.9	134	21
1.0<FA<5.0	1.95	3.19	110	39
5.0<FA	14.63	20.71	15	29
TOTAL (Mean)	0.72 g/t Au	1.05 g/t Au	874	31

Figure 2. *Comparison of 3 kg BLEG assay and fire assay data at Bendigo indicating fire assays understate BLEG assay values by 31%.*



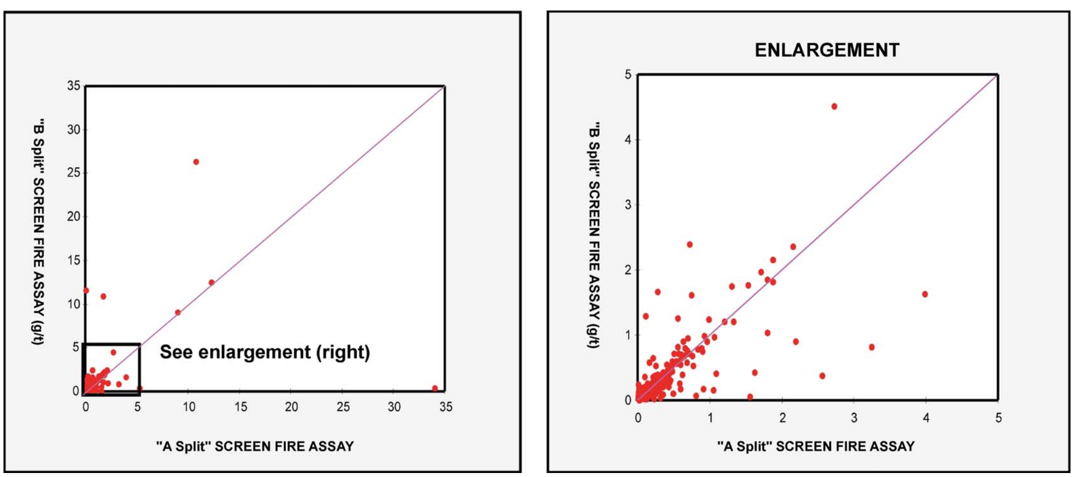
RANGE (g/t Au)	FA (Mean)	BLEG (Mean)	NO. OF SAMPLES	% UNDERSTATE
FA<0.1	0.04	0.07	313	43
0.1<FA<0.2	0.15	0.19	70	21
0.2<FA<0.3	0.25	0.34	49	26
0.3<FA<0.5	0.38	0.5	48	24
0.5<FA<1.0	0.68	0.75	30	9
1.0<FA<5.0	2.21	5.63	11	61
5.0<FA	11.16	7.83	3	-43
TOTAL (Mean)	0.25 g/t Au	0.35 g/t Au	524	29

Figure 3. *Comparison of SFA and fire assay data at Bendigo indicating fire assays understate the SFA values by 29%.*



SAMPLE GROUP	NUMBER OF SAMPLES	AVERAGE GRADE (g/t Au)
"A-split"	69	2.10
"B-split"	69	1.93

Figure 4. *BLEG assays from separate riffle splits of the same drill sample demonstrate poor repeatability.*



SAMPLE GROUP	NUMBER OF SAMPLES	AVERAGE GRADE (g/t Au)
"A-split"	524	0.35
"B-split"	524	0.34

Figure 5. *SFA from separate riffle splits of the same drill sample demonstrate poor repeatability.*

Bulk sampling and trial mining

General introduction

Bulk sampling and trial mining provides an effective way to assess grade when dealing with high nugget-effect, coarse gold bearing mineralisation. The size of a bulk sample must be carefully controlled by geological knowledge of the mineralisation from which it is to be taken. John & Thalenhorst (1991) suggest a minimum size of 0.5-1% of a total deposit (500-1000t of sample per 100 000 t of resource). This contrasts with the 2-3t of BQ core that results from drilling a deposit on 25m centres, or 8-12t on 12.5m centres (Dominy *et al*., 2001a). Before the commencement of trial mining or bulk-sampling, it is necessary to have a good understanding of the mineralisation, this is important, as it will determine the size and positioning of individual samples. If several grade and/or geological domains have been inferred or identified, then more than one sample will be necessary. If comparisons are to be drawn between trial stopes, bulk samples and other sample types, then it is essential to collect samples from a number of sites, e.g. from both low and high-grade zones and from different structures.

Bulk samples should be processed using a pilot plant or if possible, in their entirety as batches through a production-scale processing circuit. Reducing the size of a bulk sample to a smaller sample size suitable for assay is less likely to be representative of the in-situ mineralisation due to inherent errors and deficiencies in the reduction process (Bird, 1991). However, in some cases samples have been reduced via the application of a sampling tower system such as that used at Hoyle Pond, Canada (Labine, 1991). An alternative is to reduce the bulk-sample after crushing into a smaller bulk-sample (e.g. 100 t down to 15-30 t) using a statistically valid in-stream sampler prior to treatment (as used by BML). Alternatively, sample batches can be sampled in the mill circuit (after crushing) and reduced to sub-samples via a belt or falling stream sampler. Protocols such as these can be optimised using Gy Sampling Theory (Gy, 1982).

Evaluation programmes using bulk samples, require both appropriate planning and implementation. The planning stage must: delimit the nature, extent and grade of mineralisation with development sampling (e.g. diamond drilling and linear and/or panel sampling); characterise ore mineralogy (with respect to free and refractory gold); and define the size of sample required, being mindful of milling and resource estimation requirements (Dominy *et al*., 2001a).

Bendigo trial ore parcel process plant

The trial ore parcels are processed through the New Moon plant. This circuit consists of a 2 stage crushing circuit (same circuit as used in bulk sample processing) to produce a –8 mm product, which is stored in two 40t ore bins. Feed from the bins passes along a conveyor, across a weightometer into a 12 tonne per hour ball mill. The ball mill product (P80 of 600 µm) passes through two Gekko In-line Jigs and a spinner to collect a gravity concentrate. Tailings samples are collected each shift using a cutter through a falling tailing stream. The gravity concentrate is cleaned up on two shaking tables to a gold-sulphide concentrate representing between 0.5 and 1% of the original volume. Gold in concentrate is recovered as doré bars using an Intensive Leach Reactor and electrowinning cell. The weight of recovered gold plus residual gold in concentrate after leaching is combined with the estimated tailings grade to give a reconciled grade for each ore parcel.

The current processing circuit is an approximation of the planned production circuit, and some of the components (jigs, leach reactor) are of identical size to components to be used in the production circuit. This provides valuable metallurgical information and allows full-scale testing of these components.

Bendigo bulk sample processing plant

A single bulk sample usually consists of one development round with the approximate dimensions 3.5 x 3.5m profile and a 2.1m advance or 4 x 4.5m profile and a 3.5m advance. Bulk samples are stockpiled on surface before being transported to the New Moon plant.

The New Moon Plant has the capacity to treat 4 to 5 bulk samples per week at a cost of A$3000 per sample. Initially the gravity circuit operated at a feed rate of 2-2.5 tonnes per hour. However, efficiency adjustments were made to the circuit and the feed rate reduced to 1.5 tonnes per hour.

Ore is passed through the primary crushing circuit (-8 mm) and then fed to a Denver-type linear mechanical splitter. The splitter is able to take a sub-sample from 2 to 20% of the crusher feed with an option to collect 100% if required. Currently the splitter removes ~85% of the sample, which is conveyed to a reject stockpile. The remainder of the sample (~15%) is fed through a 50:50 riffle splitter, which feeds two 7.5 tonne ore bins. Each ore bin is supported on 3 strain meters to provide an accurate weight measurement.

Each duplicate sub-sample is passed through another mechanical splitter in order that a head and moisture sample can be collected before the remaining sample is passed into a hammer mill. The hammer mill is run wet, with the product re-circulated through a slotted 1-mm screen. The screen undersize is pumped to a gravity circuit consisting of two Gekko In-line spinners to recover the coarse gold. The overflow from the spinners passes through another splitter to collect a tail sample before going to the tailings dam. Figure 6 shows the processing procedure at the New Moon plant in the form of a flow diagram.

***Figure** 6. **New** Moon plant gravity circuit, Bendigo. Adapted from Johansen (2001).*

The concentrate sample taken from the In-Line spinners is sent to an external laboratory for screen fire assay. On arrival at the laboratory, the concentrate is weighed, dried and re-weighed. It is then riffle split to give two samples, one of which is sent back to the mine and the other is riffled again to give four splits. All four splits are screen fire assayed and the results re-combined to give an overall grade for the sample.

The feed to the gravity circuit is very coarse by normal metallurgical standards with 90% passing 1 mm. The circuit is designed to recover coarse gold only and the concentrate collected is typically in the order of 0.4% of the total weight processed. The inefficiency of the gravity circuit is reflected in the fact that less than 30% of the sulphides report to the concentrate. Despite the very coarse product size and the fact the gravity circuit was only designed to recover coarse gold, the plant consistently achieves high recoveries even at very low head grades. This high gravity recovery from such a coarse feed supports the historical data where throughout the field recoveries averaged 90% without the use of cyanide.

In higher-grade samples, much of the gold is extremely coarse and fails to pass through the 1 mm screen, and is thus caught in the gold trap. Because the coarsest particles did not pass through the hammer mill many of them retain their original dimensions (Figure 7).

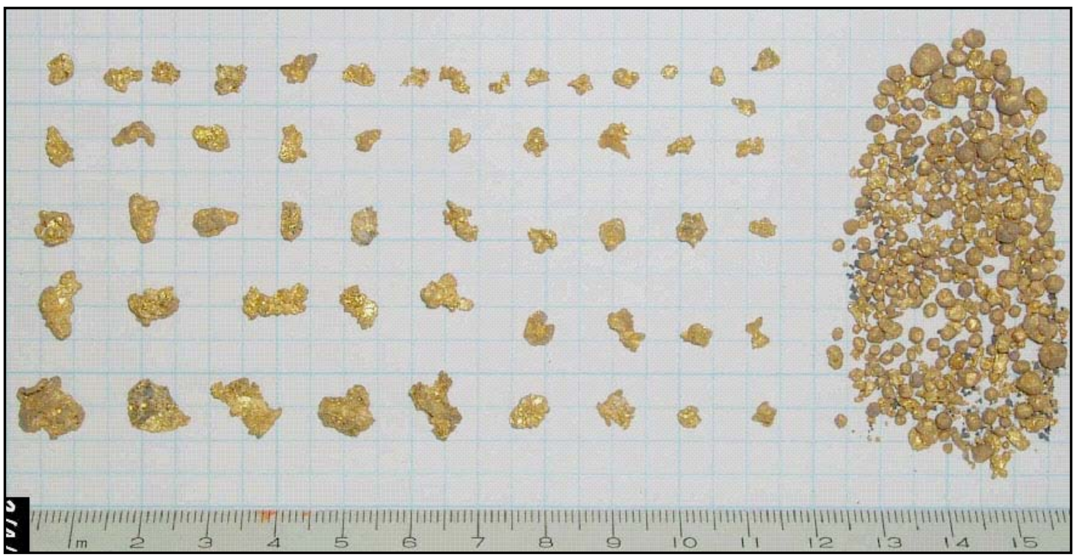


Figure 7. *Coarse gold particles collected from BS25, St. Anthony Reef, 450 South Drive. Approximately 1.5 oz was collected form the New Moon plant gold trap after 50 t treated.*

Trial sample data

Trial ore parcels at Bendigo are typically in the range of 1000 to 5000 t in size. These parcels are stoped blocks of ore, as opposed to the more spatially restricted development rounds generally used for bulk samples. They are statistically more valid, with the final grade being representative of the actual mineable grade of the development being sampled. The size of the sample better overcomes the nugget effect and erratic spatial distribution of grade within a reef. If the whole cross-sectional area of the target reef is sampled, the grade will be representative of a large volume of the reef.

Bulk sample data

Bulk samples provide a good estimate of potential grade, though are less representative than the larger trial ore parcels. In general they are spatially more restricted, and as a result, are used extensively during exploration to develop an understanding of in-situ grades and grade distribution. Bulk sampling data has also been used for comparative studies between drill samples, linear chip samples and micro-bulk samples (Figure 8). A comparative sampling study from the St. Anthony Reef is reported in Dominy *et al*. (2001a). The purpose of these studies is two fold. Firstly, they are to determine whether or not the different sampling techniques can identify the same general trends in grade, and secondly, to develop and optimise other sampling techniques (i.e. micro-bulk sampling), which have faster turn around times, are considerably cheaper and far more practical for grade control sampling. Although bulk samples are expensive and time consuming, they give the best estimate of mineable grade and are essential for metallurgical analysis.

Micro-bulk sampling

In response to the extreme nugget effect, there is a need at Bendigo for a cost effective and rapid sampling system that can be used to determine the grade of development material. Some operations have developed sampling systems based on *micro*-bulk samples, which are generally less than 1000 kg in weight (Dominy *et al.,* 2000; 2001a; Roberts *et al*., 2003).

As previously discussed bulk samples (and trial ore parcels) give the most representative estimate of grade, but they are costly in terms of time and money. As a result bulk sampling would not be suitable for grade control sampling in an operating mine. To overcome these problems, BML have instigated a 'micro' bulk-sampling circuit. Currently a single micro bulk sample consists of approximately 100 kg of rock, with two 50 kg samples taken from each on-reef development round. The grades from the two samples are averaged to give a grade for the total 100 kg.

The circuit constructed to treat a sample size of 50 kg consists of a Jaques 8'' x 5" rolls crusher (-1 mm product) mounted on a stand. A mobile 7.5" Knelson Concentrator fitted with a vibrating screen is positioned beneath. When in operation, the concentrator uses approximately 25 litres of water per minute. Expelled water flows to a sump before being re-circulated back to the concentrator (Figure 9). Excess water is treated by the site wastewater management system.

The concentrate is immediately panned, any coarse gold removed, weighed and then reconciled with the sample weight to give a rapid semi-quantitative grade. Following the removal of coarse gold the remaining concentrate along with a sample from the tailings are sent for assay. The assay values for the concentrate and tailings are then recombined with the value obtained for the coarse gold removed in order to determine a head grade.

Micro-bulk sampling, together with detailed geological mapping and observed occurrence of visible gold in the face has become a powerful tool in the delineation of ore shoots within gold-bearing reefs. With sample turn around times as low as 2 hours, micro-bulk sampling will form an integral part of future mine development. It will provide a measure of ore/waste definition, metallurgical information on gravity recovery, and gold particle size and distribution in a timely manner. The average total cost per micro-bulk sample is A$100, which is just over 3% of the cost of a macro-bulk sample.

Current micro-bulk sampling results show that compared to drill and chip samples, micro-bulk samples give an improved measure of grade potential. This is a consequence of the larger sample size and the fact that the samples are processed in their entirety. In general, micro-bulk samples do not provide values of grade that accurately reflect the mineralisation from which they represent. However, they do allow the successful delineation of ore shoots from low grade or barren zones. Mineralisation that contains substantial amounts of gravity recoverable gold is best suited to this method of sample processing. Present work is centred on the continued assessment and optimisation of the micro-bulk sampling protocols.

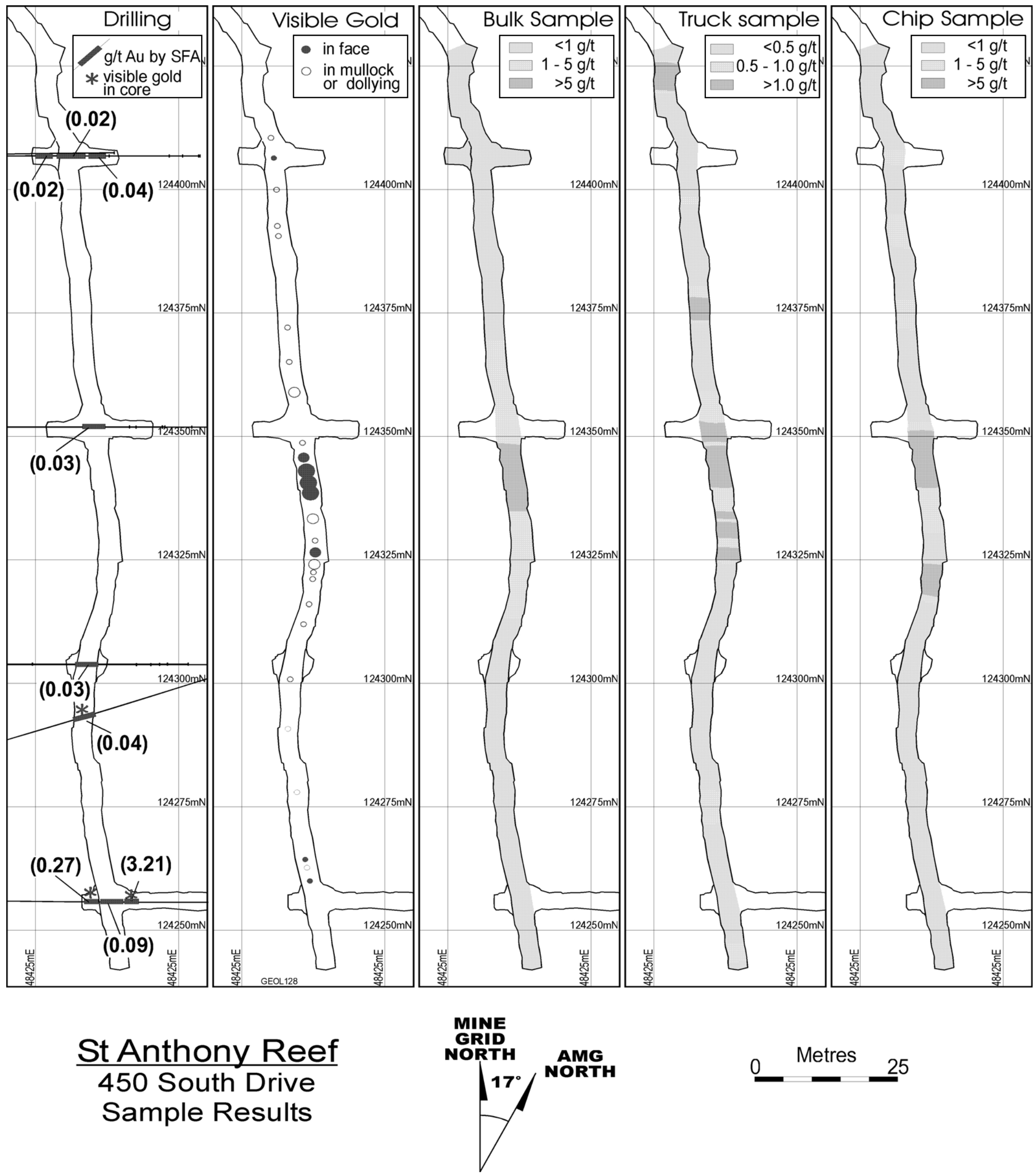


Figure 8. *Comparisons between visible gold occurrences and grades obtained from diamond drilling, bulk-sampling, truck sampling and chip sampling, 450 South Drive, St. Anthony Reef.*

Linear-chip sampling

Linear chip samples are taken for every face and sent to an external laboratory for assay. The sample size collected is relatively small, consequently, values for grade will be less representative than those obtained from bulk sampling, however, linear chip samples yield vital geological and grade domain information. Assay plans show that chip sampling picks up general trends in grade, which are also recognised by bulk sampling

(Dominy *et al*., 2001a: Figure 8) and micro-bulk samples. The combination of geological mapping and digital photographs with chip sampling data makes it possible to distinguish the single structure domains that are carrying grade. Current work is advancing this further by combining detailed, small-scale, three-dimensional modelling of vein geometry with linear-chip sample grades; this work is being carried out using Vulcan software.

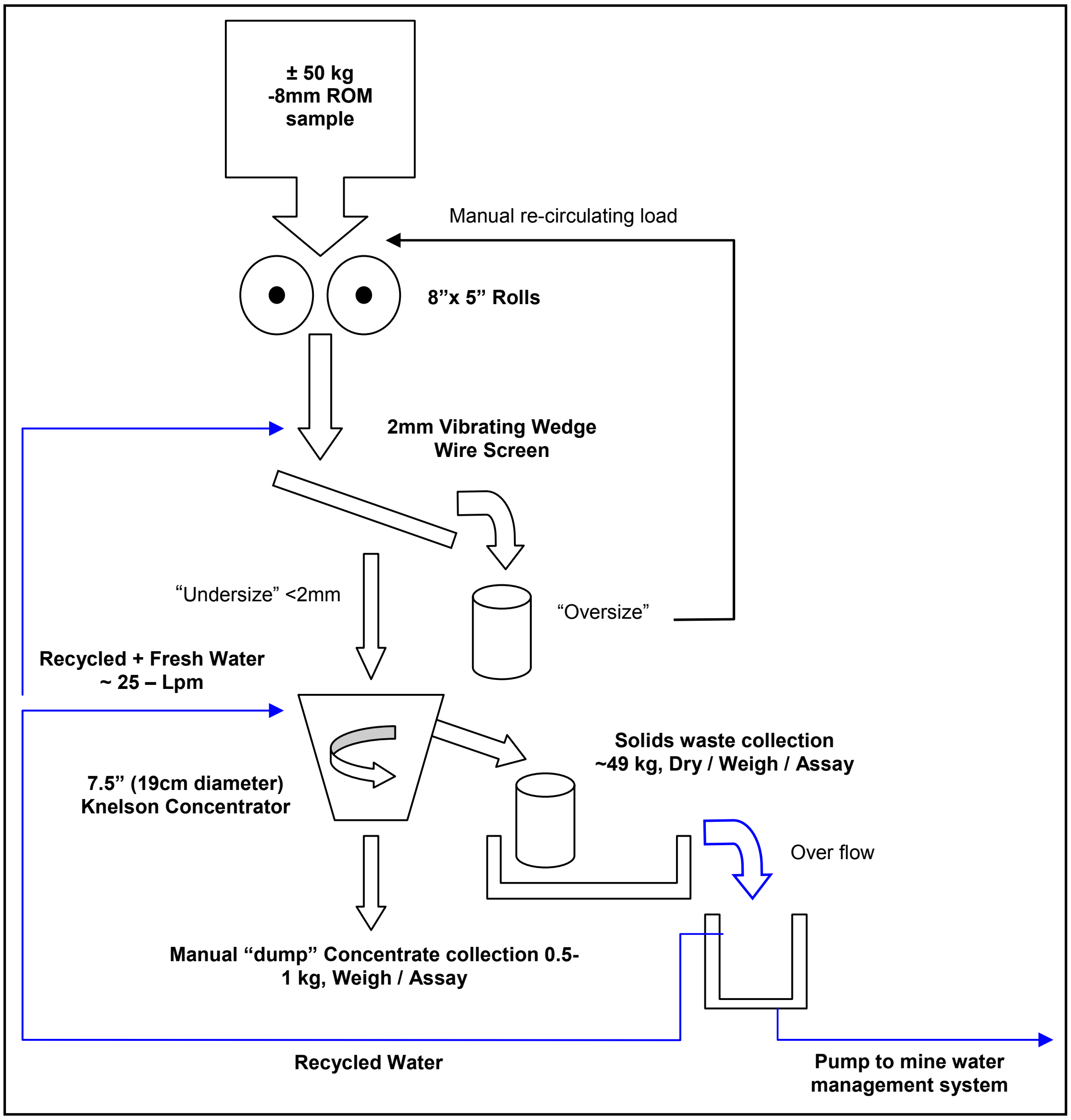


Figure 9. *Micro-bulk sampling gravity circuit.*

RESOURCE ESTIMATION AND REPORTING

As summarised previously, Bendigo is dominated by an extreme nugget effect caused by the coarse gold particle size and erratic grade distribution. As a result of various trials and research, a strategy has been developed that attempts to overcome the sampling difficulties and permit the estimation of resources and reserves. Detailed discussions of resource estimation at Bendigo are given in Johansen (2001b); Dominy *et al.* (2001a, b); and Dominy *et al*. (2003a). A brief summary follows.

Tonnage delineation

Initial diamond drilling on 100-120 m spaced sections is undertaken from the current decline, located above the target reefs. As the reefs display good geological continuity along strike, this is considered sufficient for drilling out an initial tonnage estimate. Once the decline reaches its target, fan drilling on 30-40 m sections is completed to refine the tonnage estimates. This level of drilling is expected to produce reasonably accurate tonnage estimates suitable for resource definition.

Grade estimation

It is understood that a reliable estimate of grade is only possible by using a combination of close-spaced drilling and on-reef bulk sampling. The true grade of a reef is not determinable directly from drilling. However it is believed that drilling provides an indication of grade, and important geological continuity and structural data. Bulk sampling is used to provide an estimate of reef grade, and is in some cases verified by trial mining. The location of bulk samples is based on the interpretation of drilling results, mindful of both structural setting and assay data.

Resource reporting

At the current time, it is anticipated that resources will be restricted to the Inferred and Indicated Mineral Resource categories due to the difficulty in estimating grade (Dominy *et al*., 2003a). Inferred Mineral Resources are based on drilling and some bulk sampling, and are supported by the strong gross continuity of the reefs. Indicated Mineral Resources and subsequent Probable Ore Reserves are likely to always require bulk sampling. Reporting of Probable Ore Reserves is as a best estimate within a grade range, with the proviso that all of the nominated grade range falls within the economic parameters (see Table 1).

ON-GOING RESEARCH

The preliminary studies reported in Raine *et al*. (2003) and Dominy *et al*. (2003b) are on-going and will continue to address the geological continuity and geometry of ore shoots and gold-bearing domains. A study in to the controls on gold localisation and distribution integrates textural, micro/macro-structural and geochemical data. Models for gold distribution and grade continuity are currently being developed by incorporating a detailed understanding of vein geometry, structural/textural controls on gold localisation and both reef and vein-scale grade models. The out come of this work will be integrated into sampling studies in order to advance and optimise the sampling protocols at the New Bendigo project.

CONCLUSIONS

Gold-bearing mineralisation characterised by the presence of coarse gold and an erratic grade distribution is very challenging to sample and evaluate. In such cases diamond drilling is a good measure of structure and geological continuity, but a poor measure of grade and grade continuity. Drilling combined with on-reef development, bulk sampling, trial mining and detailed geological studies are required for resource evaluation. For grade control a balance has to be sought between sample representivity, cost, turn around time and practicality. High nugget effect deposits require the use of large sample sizes (i.e. bulk samples) in order to maintain a high degree of sample representivity, however, the cost and turn around time are significant. As a result, sample size is reduced at the expense of representivity. Micro-bulk sampling attempts to overcome these problems by providing a fast, practical sampling protocol that can accurately define ore from waste. The micro-bulk sampling circuit in operation at BML is an effective means of rapid sampling in a coarse gold environment. Bulk sampling and on-reef development are still necessary for resource estimation; however, micro-bulk sampling will play an ever-increasing role in the mining operation.

APPENDIX B

APPENDIX C

Data files associated with appendix B & C have been made available in electronic format. See attached CD-ROM.

APPENDIX D

Three-dimensional translations plots and data files associated with appendix D have been made available in electronic format. See attached CD-ROM.

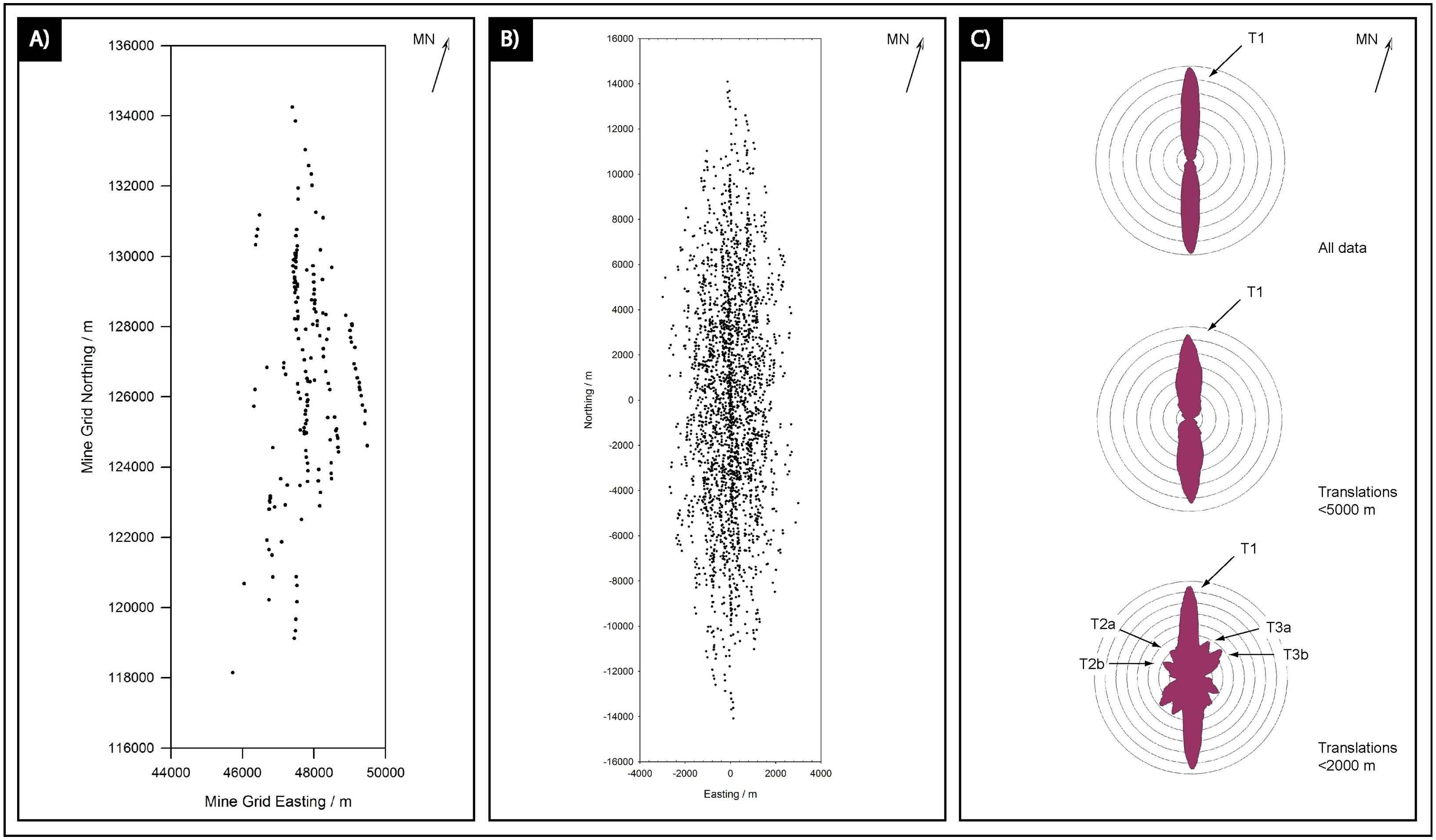


Figure 1. *A Distribution of historical shaft collars. N = 169. B. Translations for grade range 0-9.3 g/t. N = 2450. C. Corresponding MARD for translations vectors.*

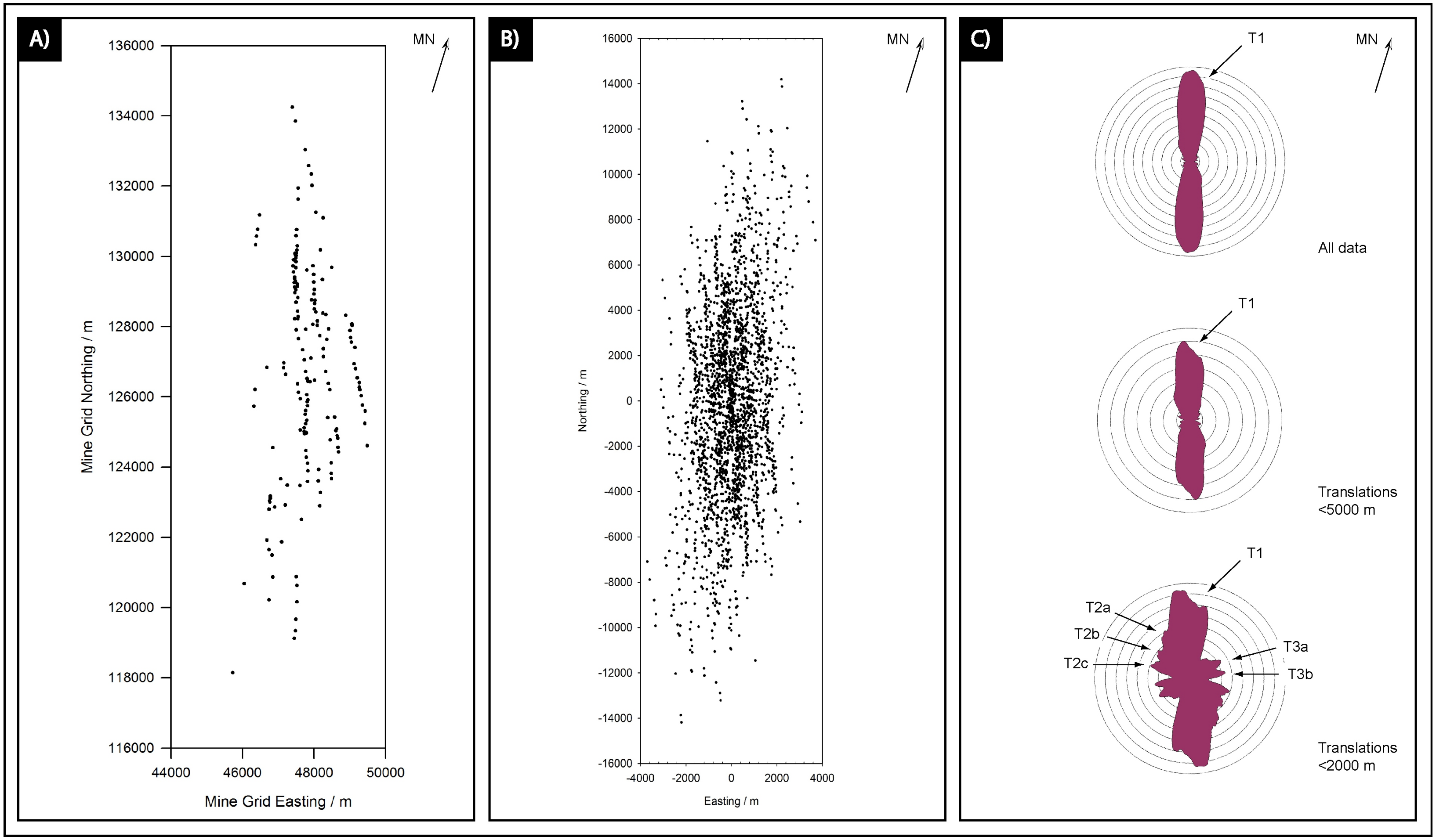


Figure 2. *A Distribution of historical shaft collars. N = 169. B. Translations for grade range 9.4-14.4 g/t. N = 2352. C. Corresponding MARD for translations vectors.*

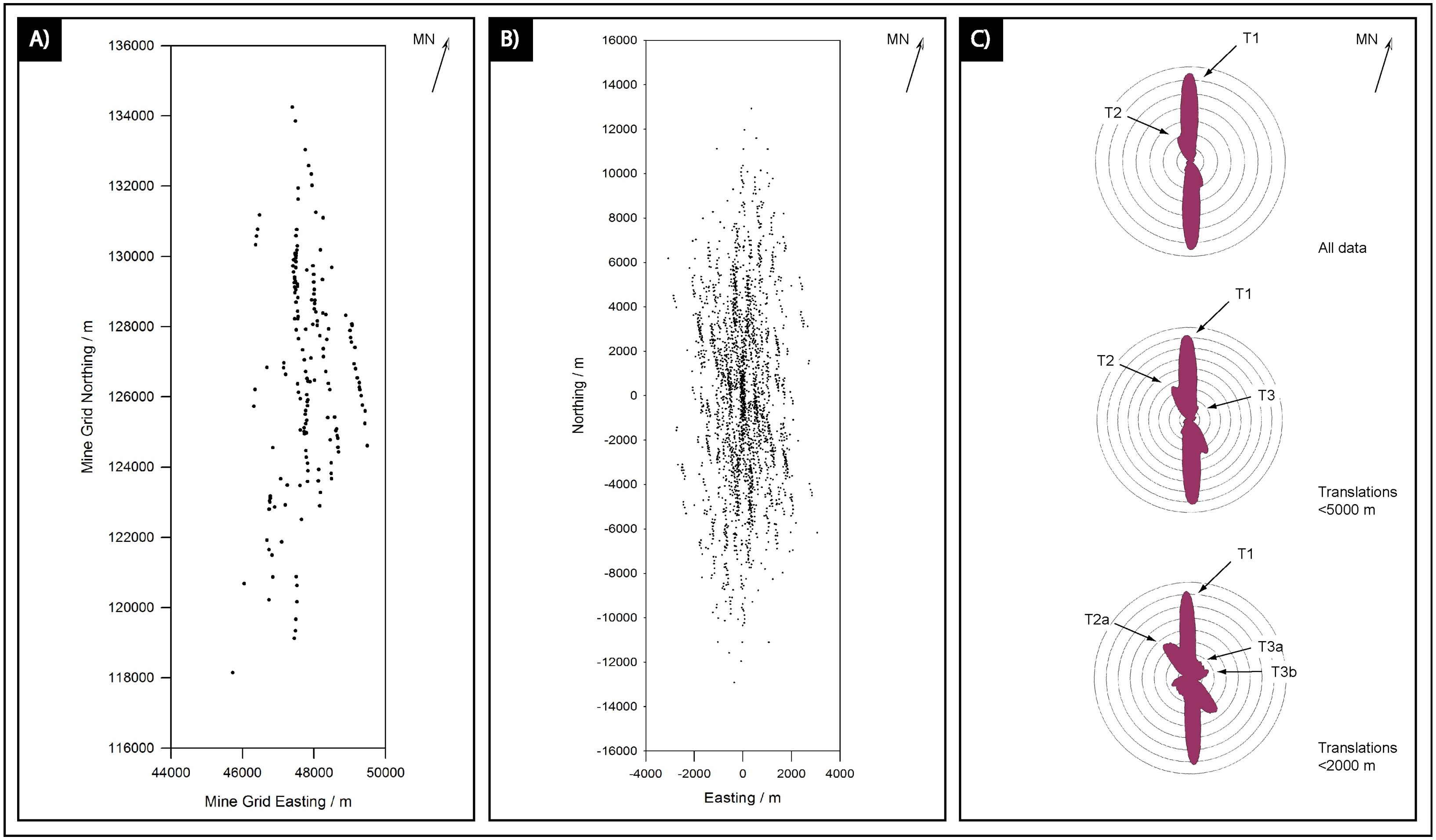


Figure 3. *A Distribution of historical shaft collars. N = 169. B. Translations for grade range 14.5-25.4 g/t. N = 2450. C. Corresponding MARD for translations vectors.*

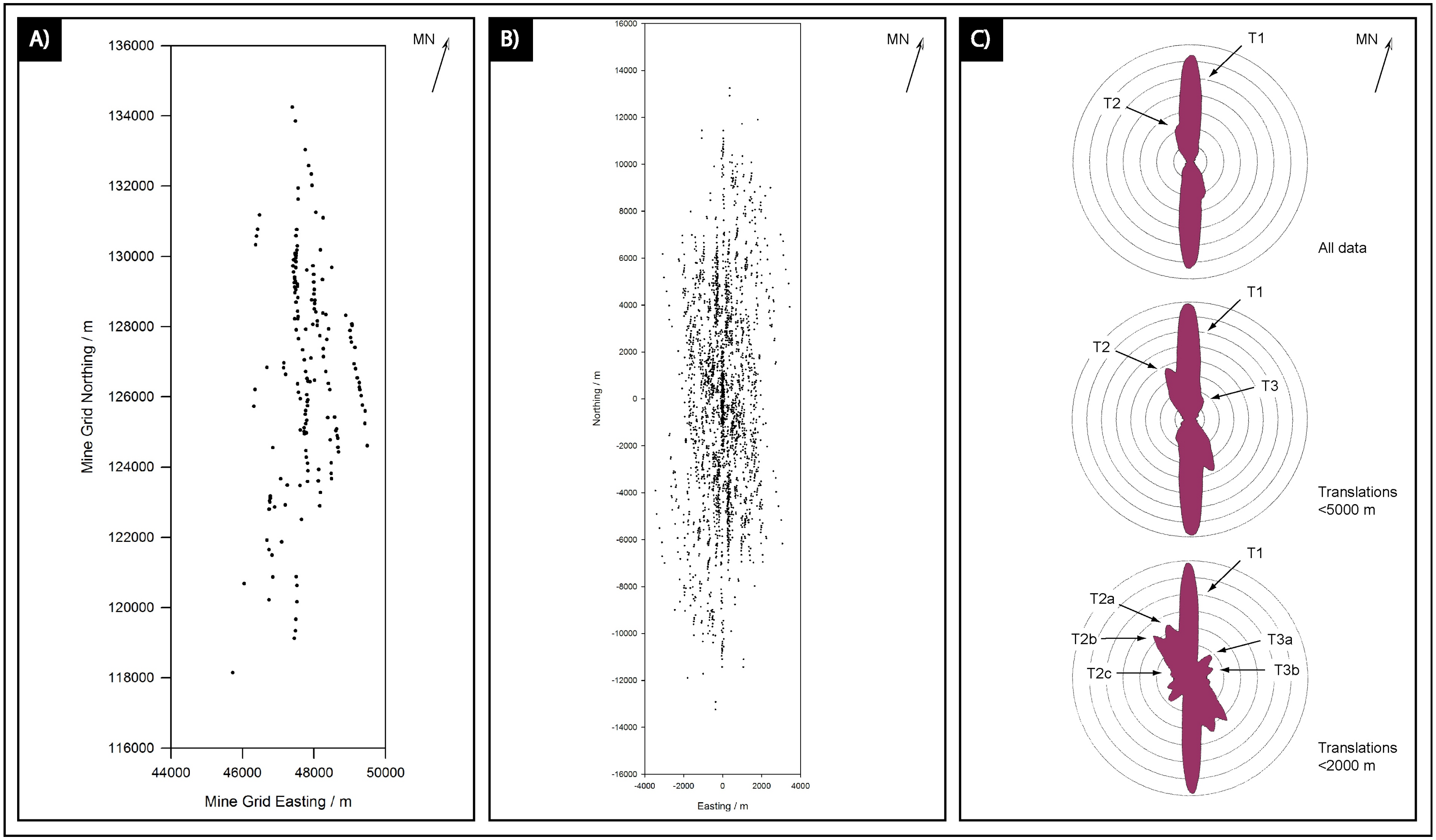


Figure 4. *A Distribution of historical shaft collars. N = 169. B. Translations for grade range 17.8-193 g/t. N = 2550. C. Corresponding MARD for translations vectors.*

APPENDIX E

JCU SAMPLE COLLECTION NUMBERS

O orientated specimen

X unorientated specimen

HS hand specimen

TS thin section

PTS polished thin section

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72036	C102		48270.793	123984.405	-552.526	O		
72037		Horizontal					O	
72038		90/345					O	
72039		90/077					O	
72040		20/075					O	
72041		40/075					O	
72042		60/075					O	
72043		20/165					O	
72044		40/165					O	
72045		20/255					O	
72046		40/255					O	
72047		60/255					O	
72048		20/345					O	
72049		40/345					O	
72050	C106		48268.046	124007.624	-555.615	O		
72051		C106					X	
72052	C107		48263.08	124010.231	-555.947	O		
72053		Horizontal					O	
72054		90/123					O	
72055		90/033					O	
72056	C113		48272.583	123980.02	-551.626	O		
72057		C113HA						O
72058		C113HB						O
72059		C113V						O
72060	C117		48263.765	124037.582	-558.810	O		
72061		Horizontal					O	
72062		90/302					O	
72063	C118		48263.085	124043.075	-559.395	O		
72064		Horizontal					O	
72065		90/340					O	
72066		90/250					O	

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72067	C200		48264.447	124045.968	-559.315	O		
72068		Horizontal					O	
72069		90/164					O	
72070		90/071					O	
72071	CT1		48265.905	124025.451	-557.416	O		
72072		Horizontal					O	
72073		90/097					O	
72074		90/007					O	
72075	D3X014		48469.7	123534.324	-350.655	O		
72076		D3X14A					O	
72077		D3X14B					O	
72078	D3X015		48470.666	123521.718	-350.514	O		
72079		Horizontal					O	
72080		90/152					O	
72081		90/242					O	
72082		20/062					O	
72083		40/062					O	
72084		20/152					O	
72085		40/152					O	
72086		20/242					O	
72087		40/242					O	
72088		20/332					O	
72089		40/332					O	
72090	G101		48216.519	124053.257	-566.128	O		
72091		Horizontal					O	
72092		90/252					O	
72093		90/340					O	
72094	G104		48220.326	124050.384	-565.633	O		
72095		G104A						O
72096		G104B						O
72097		G104C						X
72098	G111		48216.523	124090.333	-571.380	O		
72099		34/280 A						O
72100		34/280 B						O
72101	G112		48221.286	124086.828	-570.658	O		
72102		Horizontal A						O
72103		Horizontal B						O
72104	G121		48223.588	124129.857	-575.338	O		
72105		90/151 A						O
72106		90/151 B						O

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72107	G122		48215.707	124135.043	-576.928	O		
72108		Horizontal					O	
72109		90/059					O	
72110		90/149					O	
72111	G130		48214.675	124178.46	-579.938	O		
72112		Horizontal						O
72113	G131		48226.243	124189.611	-578.678	O		
72114		Horizontal					O	
72115		Horizontal 2					O	
72116		90/155					O	
72117		90/155 V2					O	
72118		90/245					O	
72119		20/065					O	
72120		40/065					O	
72121		60/065					O	
72122		20/155					O	
72123		40/155					O	
72124		60/155					O	
72125		20/245					O	
72126		40/245					O	
72127		60/245					O	
72128	G134		48217.509	124199.223	-581.387	O		
72129		Horizontal					O	
72130		Horizontal 2					O	
72131		90/354a					O	
72132		90/354b					O	
72133		90/174					O	
72134		90/259					O	
72135		20/084a					O	
72136		20/084b					O	
72137		40/084a					O	
72138		40/084b					O	
72139		60/084					O	
72140		20/174					O	
72141		40/174					O	
72142		60/174					O	
72143		20/264					O	
72144		40/264					O	
72145		60/264					O	
72146		20/354					O	
72147		40/354					O	

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72148		60/354					O	
72149	G202		48217.543	124196.301	-581.023	O		
72150		90/173						O
72151	G203		48220.033	124154.896	-578.140	X		
72152		G203A						X
72153		G203B						X
72154		G203C						X
72155	G221		48219.421	124180.273	-579.872	X		
72156		G221						X
72157	GT3		48215.879	124095.161	-572.142	O		
72158		Horizontal					O	
72159		90/081					O	
72160		90/345					O	
72161	S304		48171.374	124085.515	-401.895	X		
72162		S304V					X	
72163	S3103		48190.717	124061.926	-403.156	O		
72164		S3103A						O
72165		S3103B						O
72166	S3109		48197.172	124046.422	-404.098	O		
72167		Horizontal					O	
72168		90/174					O	
72169		20/084					O	
72170		40/084					O	
72171		20/174					O	
72172		40/174					O	
72173		20/264					O	
72174		40/264					O	
72175		20/354					O	
72176		40/354					O	
72177	S3111		48190.564	124064.673	-403.061	O		
72178		Horizontal					O	
72179		90/351					O	
72180	S3203		48192.533	124053.71	-403.521	X		
72181		S3203A						X
72182		S3203B						X
72183	S3I		48193.272	124052.796	-403.561	X		
72184		AL					X	
72185		BL					X	
72186		AX					X	
72187		BX					X	
72188		CX					X	

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72189	S3II		48192.178	124054.964	-403.418	X		
72190		3A						X
72191		3B						X
72192		3C						X
72193	S3SP1		Upper S3 Reef			X		
72194		1A						X
72195		1B						X
72196	S3SP2		Upper S3 Reef			X		
72197		3B						X
72198		4B-B						X
72199		4B-T						X
72200		6A						X
72201		7A						X
72202	S3SP3		Upper S3 Reef			X		
72203		2A						X
72204		2B						X
72205	S3SP5		Upper S3 Reef			X		
72206		2A						X
72207		2B						X
72208	S3SP6		Upper S3 Reef			X		
72209		1A						X
72210		1B-T						X
72211		1B-B						X
72212		3A						X
72213	S3SP7		Upper S3 Reef			X		
72214		3A						X
72215		4A						X
72216		4B						X
72217		5B						X
72218	S3SP8		Upper S3 Reef			X		
72219		2B						X
72220		5A						X
72221		5B						X
72222	S3SP9		Upper S3 Reef			X		
72223		2B						X
72224		3B-L						X
72225		3B-R						X
72226	SD002		48386.307	123391.715	-362.836	O		
72227		Horizontal					O	
72228		90/126					O	
72229		90/216					O	

JCU CAT. NO.	SAMPLE NO.	THIN SECTION NO.	LOCATION RELATIVE TO MINE GRID			HS	TS	PTS
			X	Y	Z			
72230	SD011		48387.986	123553.003	-363.323	O		
72231		Horizontal					X	
72232		Vertical					X	
72233	T111		48221.69	124077.301	-569.072	X		
72234		P						X
72235		N						X