

# The diamond size frequency and size quality distributions in the Argyle AK1 lamproite.

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## Introduction

The Argyle AK1 diamond mine in the east Kimberley region of Western Australia commenced production as an open cast operation in December 1985. In January 2013, mining switched to an underground block cave in the central section of the ore body. During 31 years of operation, ore treatment rates have ranged from 3.5 million tonnes per annum (M tpa) to 11 M tpa and, more recently, to 6 M tpa producing, on average, 27 M carats of lower quality and finer-tending diamonds per annum. No other primary diamond deposit has ever produced so many diamonds over its life or on an annual basis.

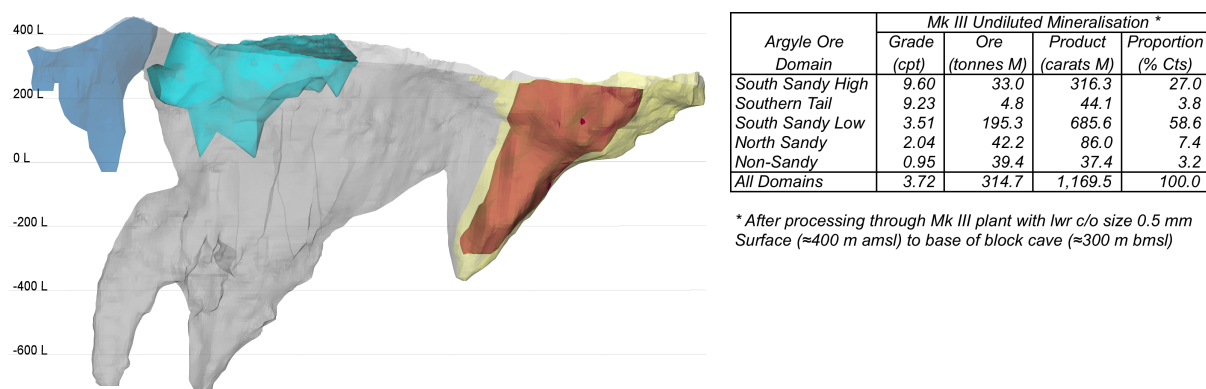
Unique features of the Argyle lamproite are the high grade and the fine diamond size frequency distribution (SFD). Early in the mine's life, Rio Tinto recognised that the micro-diamond stone counts from five metre sections of NQ drill core (about 20 kgs of lamproite) could be transformed into equivalent macro-diamond grade estimates, thereby reducing significantly the drilling and sample processing costs more usually associated with diamond ore body evaluation (Deakin & Boxer, 1989).

The robustness of this grade estimation method (be it at Argyle or for other primary source rocks) is dependent upon the in-situ diamond SFD (from 0.150 mm to 20 mm) remaining consistent. At Argyle, the diamond SFDs in the upper regions of the ore body were found to be subtly different in each of the four main ore domains, meaning that the algorithms for transforming micro-diamond stone frequencies into macro-diamond grade estimates had to be adjusted for each domain.

In 2015, changes in the diamond size quality distribution (SQD) recovered from the deeper block cave prompted Rio Tinto to conduct a thorough review of the earlier geological and volcanological models. This petrographic review revealed a series of volcanoclastic lamproites in the central section of the southern diatreme (Rayner et al, this volume) with similar diamond SFDs but differing SQDs.

## Variations in the In-Situ Diamond Size/Frequency Distribution (+0.21 mm to +1.70 mm)

The 1999-2000 deep drilling programme revealed that the AK1 deposit comprised a number of diatremes or feeders containing different lamproites (Figure 1).



**Figure 1.** 3D model of the Argyle AK1 lamproite showing ore domains as follows: from L to R, Southern Tail (dark blue), South Sandy High (light blue), South Sandy Low (grey), North Sandy (yellow), Non-Sandy (red). Accompanying table lists mineralisation based on 2016 ore body model, mostly now mined out.

The diamond size frequency distributions for each diatreme were checked for consistency and found to differ. These same differences were recognised in the production SFD and correlated with changes in the relative proportions of ore that were processed from each domain.

Drill cores and hand specimens of lamproite were dissolved to give the in-situ diamond content for samples from different locations and diatremes in the AK1 deposit (Table 1). A sub-sampling exercise conducted in the South Sandy High ore domain in 1986 revealed variations in the SFD on a local basis (Davy, 1988). More than 200 x 20 kg samples were processed in this exercise.

Sample	Sample Weight (tonnes)	Diamonds -2.36+0.21 mm *			$\Delta$ from SSL & SSH (%)	In-Situ Samp Grade >0.85 mm (carats/tonne)
		Count (stones)	Weight (carats)	MSS (carats/stone)		
South Sandy High Sample MD3 1986	1.016	6,981	13.13	0.00188	83%	10.39
Southern Tail 2003	4.938	42,841	80.45	0.00188	83%	13.71
South Sandy High Sample MD1 1986	0.840	7,078	14.51	0.00205	90%	14.88
Non-Sandy 2003	4.803	3,410	7.00	0.00205	91%	1.38
UG2 2012	33.311	77,189	166.74	0.00216	96%	4.43
UG2 >10 cpt 2012	0.856	9,586	21.04	0.00219	96%	20.46
North Sandy 2003	12.697	22,760	49.85	0.00219	97%	3.63
South Sandy Low (SSL) 2007	35.509	90,271	203.41	0.00225	100%	5.28
South Sandy (SSH + SSL) 2007	86.247	265,447	601.96	0.00227	101%	6.58
South Sandy High (SSH) 2007	10.574	67,014	152.50	0.00228	101%	14.41
South Sandy High MD2 1986	0.800	4,968	11.60	0.00233	103%	12.00

\* samples contain >20 stones in -2.36+1.70 mm size class

**Table 1:** Micro-diamond sample data for the five ore domains obtained by dissolution of lamproite with a lower cut-off size of 106 microns. Stones counts are for the size range +0.21 mm to +1.70 mm. Samples designated MD were from the 1986 programme. MSS = mean stone size.

Comparisons between the mean stone sizes for the four domains and the South Sandy Low domain over three log cycles (in carat terms) of size revealed that the Southern Tail SFD was 17% finer, the Non-Sandy SFD was 9% finer, the North Sandy SFD was 3% finer and the South Sandy High SFD was 1% coarser. Comparisons between the mean stone sizes for the three sub-samples of the South Sandy High domain and the South Sandy High domain (all samples) revealed that the Sub-sample MD3 SFD was 17% finer, Sub-sample MD1 SFD was 10% finer, Sub-sample MD2 SFD was 3% coarser and Sub-sample UG2 SFD was 4% finer than the Upper SSH.

It was not unexpected that the domains (in some cases equivalent to diatremes, Rayner et al, this volume) contained different diamond size frequency distributions, but it was important from an ore body evaluation perspective. Rio Tinto's experience at Argyle provides a benchmark for the industry; it suggests that the relationship between the micro- and macro-diamond stone counts will be unique for each diatreme, domain or geological unit (i.e. for each emplacement event). In the case of Argyle, the southern diatreme comprised the South Sandy High and the South Sandy Low domains which were contemporaneous and contained similar diamond SFDs. As a result of this similarity, Rio Tinto was able to develop a method for estimating the macro-diamond grade of 86% (by carat content) of the Argyle AK1 deposit using micro-diamond stone counts from 20 kg samples of spatially representative NQ drill core, cheaper by an order for magnitude than conventional LDC grade sampling (Deakin & Boxer, 1989).

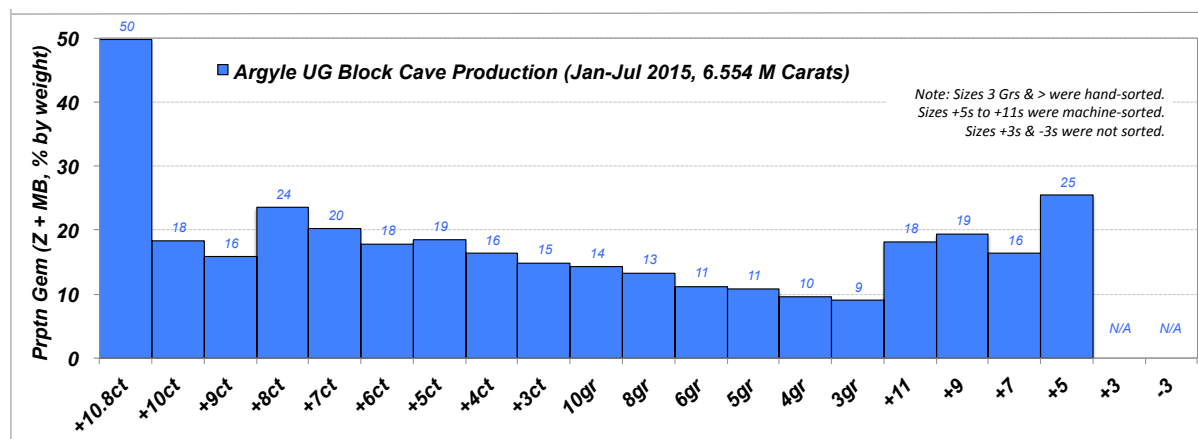
The results from the three MD samples suggest that, even within a single geological unit, the diamond SFD can vary and hence that macro-diamond sample grades estimated from micro-diamond stone counts will have +/- limits due to both sample size and local variability effects (Davy, 1988).

Roffey et al (2017) have compared the macro-diamond SFDs from sampling and production. The consistency of the macro-diamond SFD across the main South Sandy High and Low domains at Argyle was reflected in the recovered (i.e. production) SFD which has been remarkably consistent throughout the life of the mine.

### Variations in the Diamond Size/Quality Distributions (>1 DTC sieve size)

The diamond size quality distribution (SQD) in the South Sandy Low ore domain has been consistent also for many years. Changes in the SQD were observed when ore sourced from the Southern Tail and the Non-Sandy domains was treated, the former contained proportionately more lower quality diamonds and the latter contained proportionately more better quality diamonds.

Little has been published on the quality distributions of diamonds from operating mines. Gurney et al (2004) presented shape and colour distributions on the smaller diamonds from 12 kimberlites on the Ekati block. Argyle production from 2015 comprised 13% Gem, 41% Near-Gem, and 46% Bottom-End material<sup>1</sup>, but these proportions are not consistent from size to size (Figure 2); the gem quality stones increased from 9% in the 3 Grainers (0.66 to 0.89 Cts) to 24% in the 8 Cts size class. This observation has significant implications for the accuracy of modeled price estimates based on assumptions that the quality distribution in the finer size classes from smaller parcels of diamonds can be used to estimate the quality distributions and hence prices of diamonds in the coarser size classes.



**Figure 2:** Proportion of gem quality diamonds (sawables, makeables, fancy makeables, white, yellow and brown) in ROM production from the underground block cave, South Sandy Low ore domain.

## Discussion and Conclusions

It has taken almost 30 years for the internal structure and characteristics of the Argyle deposit to emerge. This situation is not uncommon on large, world-class ore bodies. There can be a tendency to assume that the status quo will continue between diatremes or with increasing depth from surface. Recognising changes in the diamond SFD and SQD is challenging because large parcels of diamonds are required in order to confirm and quantify the effects of these changes. Rio Tinto's experience at Argyle is not dissimilar to the situation it has encountered at Diavik and Murowa. For those companies new to diamond mining and for the resource geologists involved in the evaluation of primary diamond deposits (gathering Ore Body Knowledge), Rio Tinto's learnings on the variability of the SFD and SQD at Argyle should provide a reality check and a reason to reflect on the robustness of their global resource estimates.

## References

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<sup>1</sup> Explanatory notes on the diamond sizing process and Rio Tinto's diamond quality sorting matrix are provided in Appendices 1 & 2 respectively.