9th International Kimberlite Conference Extended Abstract No. 9IKC-A-00331, 2008

Diamonds: Exploration, Mining and Marketing

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Introduction

The most significant diamond discovered since the 8IKC in Victoria in 2003 is the 603 carat Lesotho Promise recovered in August 2006 from Gem Diamonds Limited's Letseng le Terai Mine in the northeastern highlands of the Kingdom of Lesotho. This diamond was tendered in Antwerp by WWW International Diamond Consultants and the rough stone was sold for US$12.4 million ($20,564 per carat) to Graff Diamonds of London. From the 603 carat rough, Graff manufactured 26 D flawless polished gems ranging from 0.55 to 75 carats, with a total weight of 224 carats. This unique set of the finest quality goods is expected to sell for in excess of $25 million.

At this conference we will look beyond the economics of this $13.9 billion per annum diamond industry and use kimberlites, lamproites, diamonds and mantle xenoliths as windows on the lithosphere and asthenosphere and, in so doing, attempt to explain diamond genesis in space and time and the relationship to the formation of the continental lithosphere. The physics and volcanology of kimberlites, as the transporting medium of diamond and associated xenoliths, between lithosphere and crust, will also be examined in detail.

Diamond Mining

The Kimberley Process Certificate (KPC) that monitors world rough diamond trade was instituted in late 2002 shortly before the 8IKC. Not only does the KPC attempt to prevent the trade in conflict diamonds but it also provides a useful audit of rough diamond trade from producers to merchants and manufacturers. In 2007 diamonds weighing some 173 million carats and worth approximately $13.9 billion (world average for kimberlite and alluvial diamonds: $80 per carat) were produced in some 20 countries with Botswana, Russia, Canada, South Africa and Angola being the top five producers by value. Since the 8IKC, Gurney et al (2005) and Janse (2007) have published detailed reviews of diamond crustal distribution and global diamond production, respectively. Table 1 is updated from Janse (2007) and lists diamonds mines that have reached production in the past 10 years, mines under construction, in addition to exploration projects at an advanced stage of evaluation, which have the potential to become future mines.

Among the mines and potential mines listed in Table 1 a number of these kimberlites differ from the classic criteria of mines such as Mir, Jwaneng, Orapa, Venetia, Diavik and Ekati. Gem Diamond's Letseng has very low grade (1.72 cpht) with extreme diamond value ($1,996 per carat) as a consequence of a coarse size frequency distribution for the diamond population. At Letseng some 81 percent of mine revenue is derived from specials (stones greater than 10.8 carats). De Beers' Victor is a relatively small deposit (16 hectares) but with high value goods ($450 per carat) located in the muskeg of the James Bay Lowlands of northern Ontario.

Kimberlites which were originally discovered in the 1970's and 80's are being re-examined and, in light of the strong market for rough, are proving to be economic (Liquobong, Kao, Gope, and Ellendale). Shore Gold Inc. is in the process of evaluating the very large (e.g. Star: 352 hectares) kimberlites of the Fort à la Corne area of central Saskatchewan. These kimberlites have huge tonnage, high value diamonds (e.g. Star: $170 per carat), relatively low grade and are buried under approximately 100 metres of overburden. Kimberlites previously discovered in Angola are being mined and developed now that the civil war has ended. Some older mines have changed hands (Koffiefontein, De Beers to Petra and Lerala, De Beers to DiamonEx) and are being redeveloped under new operating conditions that suggest strong economics.

The four major companies still produce a large share of the world's diamond budget: De Beers (2007 Production 51 million carats, Sales $5.92 billion), Rio Tinto (2007 Production 26 million carats), Alrosa (2006 Sales $2.3 billion) and BHP-Billiton (2007 Production 3.2 million carats). After the four majors, the publicly traded diamond companies can be compared by the size of their market capitalization and the top five are: Harry Winston Diamond Corporation, Gem Diamonds Limited, Shore Gold Inc (not yet a producer), Petra Diamonds Limited and Namakwa Diamonds Limited. In Russia, Severlamaz, which discovered the Pomorskaya Pipe in the Lomonosov Diamond Field near Archangel in 1980, reached production in 2005 and in 2008 held the first auction when diamonds were offered for sale to both Russian and foreign merchants. Archangel Diamond Corporation has recently reached agreement with LUKOIL regarding the ownership and development of the Verkhotina diamond project and published a

preliminary assessment for the Grib Pipe. In Brazil, Vaaldiam Resources has consolidated the Duas Barras and Chapada alluvial projects into one company and have reached production, in addition to continued evaluation of a number of diamondiferous kimberlites.

Table 1. Diamond mines recently in production, under construction and advanced evaluation projects.

Name of project/mine	Majority owner	Country	Size (ha)	Year of opening	Capital cost (M$)	Ore reserves (Mt)	Grade (cpht)	Reserves (Mct)	Value ($/ct)	Value ($/t)	Value (M$)	Projected production (Mct/yr)	Projected life (yr)
Camafuca	Endiama & Mwana	Angola	160	2007	25	13	24	5.2	117	26	608	0.2	5
Catoca	Alrosa & Endiama	Angola	66	1997	-	271	72	189	70	53	14,000	6.7	20
Camatchia-Camagico	Alrosa & Endiama	Angola	28	2008	-	80	17	13.6	200	-	-	-	-
Argyle UG	Rio Tinto	Australia	12	2008	800	100	370	370	13	48	1,200	16	10
Ellendale	Gem Diamonds	Australia	-	2002	-	105	5	5.25	220	11	1,155	0.7	-
Lerala	DiamonEx	Botswana		2008	-	13.5	27	3.6	60	16	216	0.33	10
AK06	African Diamonds & De Beers	Botswana	9.5	-	-	11.1	24	2.7	150	36	1,665	-	-
Gope	Gem Diamonds	Botswana	25	-	-	97	19	18	131	25	2,400	-	-
Renard	Stornoway	Canada	-	-	-	-	-	-	-	-	-	2	10
Star	Shore Gold	Canada	352	-	-	-	-	-	-	-	-	-	-
Orion	Shore Gold /Newmont	Canada	-	-	-	-	-	-	-	-	-	-	-
Jericho	Tahera	Canada	3	2006	90	2.6	55	3.1	99	108	280	0.4	8
Snap Lake	De Beers	Canada	15	2007	975	23	146	33	76	111	2,500	1.5	20
Victor	De Beers	Canada	16	2009	975	27.4	23	6.3	450	105	2,850	0.6	12
Gahcho Kué	De Beers	Canada	3	2012	745	14.4	164	23.6	77	126	1,800	1	20
Ekati	BHPB	Canada	11	1998	880	78	109	3.1	84	92	7,100	5	17
Diavik	Rio Tinto	Canada	5	2003	1,170	27	395	9.8	62	245	6,300	8	20
Letseng	Gem Diamonds	Lesotho	15	2003	-	-	1.72	-	1,996	-	-	5.2	33
Liquobong	Kopane Diamond	Lesotho	1.5	2005	100	55.5	27.6	15	70	19	285	3.5	16
Kao	Global Diamond	Lesotho	20.8	-	-	-	6.9	-	200	-	-	-	-
Grib	ADC/AGD	Russia	14	-	-	98	69	67	79	53	5,300	4	20
Arkhangelskaya	Severalmaz	Russia	45	2006	400	110	52	57	48	25	2,740	5-6	20
Koffiefontein	Petra	South Africa	10	2007	-	-	8.2	-	484	-	-	-	-
Voorspoed	De Beers	South Africa	12.5	2008	172	8.3	-	-	-	-	-	0.7	12
SA Sea Areas	De Beers	South Africa	-	-	-	4.5	-	-	-	-	-	0.2	30
Lace	Diamond Corp	South Africa	-	2007	-	34.8	39	13	-	-	-	-	16
Murowa	Rio Tinto	Zimbabwe	4	2004	61	19	90	17	65	63	1,200	0.5	17

Note: Table 1 relies on information publicly available and some information is incomplete. These values may change as new information is made available by operating companies.

Diamond Exploration

High levels of expenditure continue in diamond exploration world wide. In Canada, exploration budgeted at over $300 million focused on a wider area than at the time of the 8IKC, particularly as discoveries were made in the eastern Arctic of Nunavut, Canada. Stornoway Diamond Corporation had discovered the Aviat diamondiferous kimberlites on the Melville Peninsula in early 2003 just prior to the 8IKC. Since this discovery in the eastern Arctic, exploration efforts by Shear Minerals (Kahuna Kimberlite west of Baker Lake), Diamonds North (Amaruk Kimberlites south of Pelly Bay) and Peregrine Diamonds (Nanuq Kimberlites west of Wager Bay) have led to the discovery of several diamondiferous kimberlites.

The most significant exploration expenditure worldwide is on the evaluation of the Fort à la Corne kimberlites of central Saskatchewan by Shore Gold Inc. and their joint venture partner Newmont Mining, where there is an operating budget of $107 million for 2008. These very large relatively low grade kimberlites buried under 100 metres of predominantly glacial overburden required the application of a number of specific techniques for their discovery, delineation and evaluation. These kimberlites were discovered using airborne magnetics and drilling and specific algorithms applied to electromagnetic surveys have proved to be the best method of delineation of the boundaries of these kimberlites.

At the time of kimberlite discovery in 1989 the exact tectonic setting of this part of Saskatchewan was uncertain due to extensive Cretaceous sedimentary cover rocks overlain by extensive glacial till and outwash sands. Seismic profiling across the Glennie Domain within the Trans-Hudson Orogen suggested the presence of the Sask Craton which has been further confirmed by geochronology of deep crustal rocks from drilling and kimberlite xenoliths, in addition to

the final confirmation of a cool cratonic geotherm (37 mWm^{-2}) using the clinopyroxene thermobarometry of Nimis and Taylor (2000). Clinopyroxene thermobarometry conclusively defines a cratonic geotherm and a lithospheric base that corresponds with the 220 kilometre depth indicated by the seismic profiling. Bulk sampling methods for these kimberlites include shaft sinking and underground drift development and large diameter drilling using a combination of kelly-bar drilling for the softer overburden and reverse circulation drilling for the more competent kimberlite. This was the first application of these two drilling methods using a Bauer BG36 rig.

Diamond exploration continues in Africa (Angola, DRC, Gabon, Botswana, Tanzania, and South Africa), Russia, Australia, Brazil, Madagascar and India, where Rio Tinto geologists discovered the eight Bunder Kimberlites in 2004. Exploration techniques include higher resolution geophysical techniques operating from a variety of platforms including fixed and rotary winged aircraft and recently De Beers has operated a gravity system from a lighter than air airship. Dense media separators are seeing more frequent application to the processing of prospecting samples. Tools to interpret indicator mineral chemistry of prospecting samples are much improved and their use being well documented in the literature (e.g. Nowicki et al, 2007). Shore Gold Inc. has successfully collected a sizeable database of kimberlite clast size and species measurements and is investigating the relationship to diamond grade. High resolution digital terrain models produced by NASA's Shuttle Radar Topography Mission serve as useful base maps for the interpretation of indicator sampling results.

Diamond Marketing

The market for rough diamonds is strong and prices have risen some 30 percent in the past year. The outlook for the diamond market suggests that demand in the not too distant future will be considerably larger than supply and there is the suggestion that the peak world diamond production will soon be passed (Janse, pers. comm.). The outlook for current and future producers is good and there will be a role for gem quality synthetics in an under-supplied market. As a result of the processing of huge quantities of goods from Argyle, the Indian cutting and polishing industry has become the largest in the world. There are changes to the diamond supply chain with the DTC holding diamond sights in southern Africa. In addition, a number of African producers are requiring a significant proportion of local beneficiation. The role of De Beers in the diamond market has changed. The United States is still the largest consumer of gem diamonds but significant markets are emerging in the Middle East, India and China. The total polished diamond content in worldwide jewelry sales has now past the $20 billion mark for the first time, on total diamond jewelry sales of $73 billion (Chaim Even Zohar, IDEX Online May 6, 2008). At a recent conference in Tel Aviv, Alrosa president, Sergei Vybornov, suggested that Russia has proven reserves of some $110 billion which will ensure that Russia will be a supplier well into the future.

Diamond Genesis in Space and Time

It was just over 20 years ago that Stephen Richardson and coworkers first confirmed the ancient origin of diamonds and that they occur as xenocrysts in kimberlites. At the 8IKC there was considerable discussion of the relationship between diamond growth and metasomatism. In addition, kimberlite volcanology and the physics of eruption have seen extensive work. We now have the task of evolving recent developments and synthesizing all aspects of diamond genesis as a secondary mantle process and the transport of diamonds from mantle depth to the surface by kimberlite magmas.

On the micro-scale Navon and coworkers (pers. com. 2008), through the analysis of micro-inclusions in diamond, are able to show that fluids of different compositions are responsible for successive generations of diamond growth and simultaneously supplied the carbon. On the macro-scale, Pearson and Wittig (2008) examine the formation of Archaean continental lithosphere and, through accurate chronology of xenoliths, diamonds and lithospheric events propose that "most diamonds form in the cratonic roots during pulses of thermal and tectonic activity". Navon's fluids and Pearson's pulses are essentially equivalent and the model suggests that diamonds are secondary minerals that form by metasomatic processes in continental lithospheric rocks at specific times in earth history. These diamond forming events can be correlated with major tectonic events in the lithosphere.

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