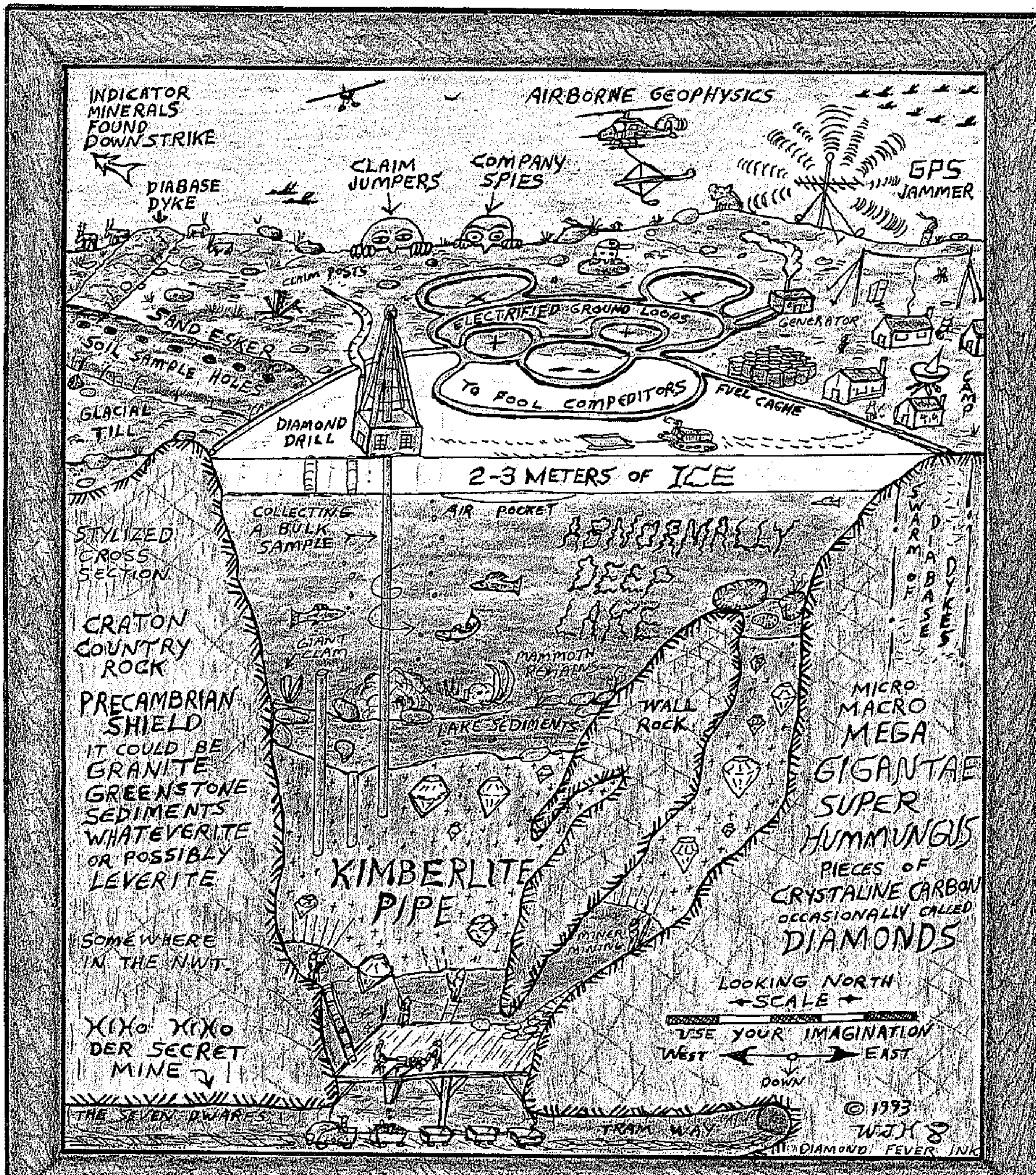
DIAMONDS
AND
THE NORTHWEST TERRITORIES, CANADA



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Webster Galleries (YK) Ltd
Box 1597
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MINISTER'S INTRODUCTION

The diamond discoveries and the associated staking rush in the Northwest Territories (NWT) have focused the interest of the world on the North's mineral potential. News articles have appeared in papers from New York to Tokyo, as well as all the major Canadian cities. This excitement has left many residents curious about the opportunities associated with this new potential industry.

However, the diamond industry as a whole is complex, secretive and unique, and most Northerners have little information about it. As a first step in helping NWT residents understand the diamond industry, the Department of Energy, Mines and Petroleum Resources has compiled this report on diamonds and the potential future presence of diamond mining in the NWT.

It is our intention to ensure that residents are prepared to take part in any future development. A new gem diamond mining district in the NWT would offer jobs, new businesses, increased revenue and new infrastructure developments. The best way to take advantage of these opportunities is to build a partnership between the communities, industry and government.

John Todd
Minister
Energy, Mines and Petroleum Resources

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ENERGY, MINES AND PETROLEUM RESOURCES
GOVERNMENT OF THE NORTHWEST TERRITORIES

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SUMMARY

Natural rough gem diamonds are worth hundreds to thousands of dollars per carat. Some 40 to 50 million carats of uncut rough diamonds worth US$6 billion are sold annually to yield 15 million carats of cut and polished diamond gemstones that, in turn, are set into jewellery that retails for up to US$40 billion. This flow from the mines to the jewellery stores of the world is called the diamond pipeline. The mining and marketing of the highest priced commodity in the world is directed by a company called De Beers.

Diamond mining has, by far, the lowest concentration and the most variable product of all natural commodities. There are over 5,000 classifications for rough diamonds. Broadly speaking, uncut diamonds can be sorted into industrial, near-gem or gem categories. Perhaps two-thirds of all diamonds ever mined are of industrial grade or too small for cutting and polishing into valuable gemstones. Diamonds of industrial grade have been manufactured synthetically since 1955.

The majority of natural diamonds have been mined from unique vertical intrusions called kimberlite pipes. Diamonds form at depths of 150 kilometres or more within the Earth and are transported explosively to the surface by a gas-charged igneous rock called kimberlite. The kimberlite-hosted diamond deposit takes the form of a downward-tapering pipe of one to two kilometres vertical extent and up to 500 metres across at the surface. Diamond-bearing pipes are found in clusters. Clusters are restricted to the ancient Precambrian Shields of the world. Diamonds have been mined from ten pipes in South Africa since 1870, from seven pipes in Siberian Russia since 1960 and from three pipes in Botswana since 1971. Individual kimberlite pipe mines are found in Zaire and Tanzania, and a lamproite deposit is mined for diamonds in Australia.

Although not easily found, kimberlite pipes can be discovered by modern exploration techniques. A heavy mineral sampling program evaluates surficial material for hard, dense, distinctive grains of minerals eroded from a kimberlite pipe. Ground sampling for the indicator minerals of purple pyrope garnet, green chrome diopside, picroilmenite and chrome spinel, when combined with airborne geophysics, may yield targets that are tested by drilling. It may take a decade or more to discover a diamond-bearing pipe of economic potential, and a further six or more years to bring a mine into production.

Diamond mines start as open pit operations and operate for 30 or more years. The recovery of diamonds from kimberlite relies on mechanical processes and not chemical leaching. Tailings consist of fine sand-sized material which, in general, is not acid-forming and does not contain sulphide metals. A large diamond mine, on average, recovers 4.5 million carats or about a tonne of diamonds valued at $US450 million from five million tonnes of ore mined annually. An *in situ* reserve of 500 million carats consisting of 30% gem quality diamonds and contained in one or more pipes, may be valued at $US50 billion. Therefore, a potential topnotch diamond mining region has a value equivalent to ten Yellowknife gold mining districts.

A diamond-bearing kimberlite pipe was drilled in 1991 at Lac de Gras in the central mainland Northwest Territories. The news release triggered the largest land staking rush in Canada, now into its third year. Exploration has shown the initial discovery to be part of a cluster of more than 62 kimberlite pipes. Preliminary work to date indicates that several pipes have gem diamond concentrations and valuations comparable to diamond mines in Africa. BHP Minerals and Kennecott Canada are separately proceeding to bulk sample two or more pipes and one double pipe, respectively in 1994. Bulk sampling will generate the economic parameters required for production decisions.

The exploration and evaluation of gem diamond deposits with economic potential continues unabated at Lac de Gras. The communities, businesses, mining industry and government of the Northwest Territories are preparing for the opportunities that a development of this magnitude would offer.

DIAMONDS AND THE NORTHWEST TERRITORIES, CANADA

INTRODUCTION

> **World-wide some three hundred million women own at least one piece of diamond jewellery, and each year husbands, lovers and women themselves spend almost forty billion dollars on about sixty million pieces containing some fifteen million carats of diamonds.** 1

A diamond staking rush has entered its third year in the Northwest Territories (NWT). The discovery of diamond-bearing deposits has drawn the attention of the world. Financially supporting the flurry of staking, exploration, drilling and bulk sampling at Lac de Gras, central mainland NWT are three of the world's largest international mining companies - **BHP Minerals**, **Rio Tinto Zinc** (**RTZ**) and **De Beers**. At stake are potential diamond mines worth billions of dollars.

As the evaluation of gem diamond deposits with economic potential continues at Lac de Gras, the communities, businesses and government of the NWT are preparing for the opportunities that a mining region of this magnitude would offer Northerners. The NWT has grown through the development of its rich natural resources. It was fur in the 1920s, gold in the 1940s and oil in the 1980s. Will it be diamonds by the year 2000?

The Department of Energy, Mines and Petroleum Resources of the Government of the Northwest Territories has researched literature available to the public for information on the geology, exploration, mining, processing and marketing of diamonds. The purpose of this paper is to provide the reader with background information on the NWT diamond rush. The data in this report has been compiled from numerous sources. References are listed should more detailed information be required.

DIAMOND, THE MINERAL

The mineral, diamond, is a hard, dense crystalline form of carbon. A more familiar form of carbon is graphite, such as the "lead" in a pencil. Carbon, when compressed under high pressure and moderate temperature, forms diamond. In nature, this pressure occurs 150 or more kilometres (km) beneath the Earth's surface.[2]

The name "diamond" can be traced back through the Old French word *diamant* to the Medieval Latin word *diamas*. *Diamas* or "cannot be tested" is derived from the Greek word *adamas* which means "invincible".[3]

A diamond is the hardest of all known substances. Other general properties of a diamond include a very high conductance of heat, poor conductance of electricity, fluorescence when X-rayed, adherence to grease and brittleness due to cleavage.[4] A diamond has a specific gravity of 3.5 which is about a third more dense than typical rock.

Diamonds may be any colour from colourless to black. Only the transparent diamond crystals will become gems. When cut and polished, gem diamonds have the very high "brilliance" and "fire" much prized by gem fanciers. Brilliance is a measure of the white light reflected and refracted by the crystal faces of the cut and polished jewel. Fire is the array of spectral colours dispersed from the gemstone.

UNITS OF MEASURE

The jeweller's units of measurement for diamonds are the "carat" and the "point". First adopted by ancient pearl merchants, the word "carat" was derived from the Greek word *keration*, the name for the carob tree common to the Middle East.[5] The carob tree's pod-like fruit contains seeds that are very uniform in weight. It was not until the early twentieth century that the weight for the "carat" was standardized to 0.2 grams.

Some Diamond Measurements

1 Carat = 100 Points	Microdiamond < 0.5 Millimetre
1 Carat = 0.2 Gram	Macrodiamond > 0.5 Millimetre
5000 Carats = 1 Kilogram	

A microdiamond is the size of a fine grain of sand[6] Mining operations will recover a diamond as small as 2 millimetre (mm) or the size of a coarse sand grain, which weighs about 0.1 carat. A one carat brilliant cut stone is about 6.5 mm or 1/4 inch in diameter. The largest natural gem quality diamond ever recovered, the Cullinan weighed 3106 carats (0.62 kg) or slightly less than 1.5 pounds.

HIGHLIGHTS FROM THE HISTORY OF DIAMONDS [7 to 11]

Antiquity	- Diamonds were mined from river gravels in India, yielding perhaps 21 million carats during the past 20 centuries. The Kohinoor and Hope diamonds were found in India. The diamond cutting industry started in India. Diamonds were split by hammer and chisel. Facets were polished onto a gemstone by grinding it with another diamond. Diamonds were also found to a lesser extent, since antiquity, in river gravels in Indonesia and China and, since the 1600s, in placer deposits in the Russian Ural Mountains.
1400s	- A Belgian diamond cutter invented the "scaif", a horizontal grinding wheel coated with oil and diamond dust, allowing the consistent grinding and polishing of diamonds. A diamond cutting industry flourished at Antwerp, Belgium supplying European aristocracy with diamond gemstones.
1725	- Diamond rush in Brazil with diamonds found in the gravels of many rivers. First recorded crash in diamond prices. Historically, gem diamond production was marketed through the London-based Diamond Syndicate; gemstones were cut and polished in Antwerp, Belgium. Brazilian placer or "alluvial" deposits supplied about 50 million carats to 1990.
1866	- First documented discovery of diamonds in Africa, near Hopetown in South Africa, in the gravel of the Orange River. The modern era of gem diamond mining began with the ensuing rush.
1869	- Discovery of five vertical orebodies called "pipes" at Kimberley, South Africa. From 1870 on, a swelling flood of small gem diamonds required greater numbers of diamond cutters who would increasingly rely on mechanized processes. South Africa has produced about 450 million carats of diamonds from nine major pipe deposits (30% gem ratio), numerous smaller occurrences and several alluvial fields (60% gem ratio) to 1990.
1888	- Formation of **De Beers** by Cecil Rhodes, who started his African empire-building career by consolidating the crucial properties at the South African diamond "diggings". **De Beers** merged the South African diamond production with the London-based diamond marketing interests.
1905	- Discovery of world's largest diamond (3106 carat Cullinan) at the Premier mine, South Africa, from which the two largest gemstones in the British Crown Jewels were cut and polished.
1907	- Diamonds discovered in Zaire. About 720 million carats (6% gem ratio) recovered from placer deposits and one pipe deposit to 1990.
1908	- Rich beach deposits of Namibia were discovered. About 60 million carats (95% gem ratio) recovered to 1990. Diamonds were discovered in the rivers of western African countries during the next two decades. Significant producers to the present day include Angola, Ghana, Guinea, Ivory Coast, Liberia and Sierra Leone.
1919	- A mathematician named Tolkowsky calculated the "Ideal" proportions to optimize the brilliance, fire and scintillation from a diamond. The "Ideal" cut became the standard for the jewellery trade.
1930	- South African mining magnate, Sir Earnest Oppenheimer, became chairman of **De Beers**. Oppenheimer set up the **Diamond Corporation** and the **Diamond Trading Company** in London which are the marketing arms of the Central Selling Organization.
Post-WW II	- Demand for gem diamonds grew substantially.
1955	- USA company, **General Electric**, patented the synthesis of industrial grade diamond by mechanical means.
1956	- Diamond pipes discovered in Yakutia region of Siberian Russia. Estimated 270 million carats recovered from six pipe deposits and minor alluvial operations to 1990. The major Russian cutting industry was established during the 1960s.
1966	- First of three diamond mines discovered by **De Beers** in Botswana. Producer, **Debswana** is owned equally by **De Beers** and the Botswana Government, with 150 million carats recovered to 1990. Israeli interests established a major cutting industry with mechanized "production line" factories during the 1970s due, in part, to the development of the Botswana mining region.
1978	- The discovery of the Argyle mine, the world's largest producer of diamonds (40 million carats per year at 5% gem ratio) in Australia, with *in situ* reserves of 500 million carats. The tremendous growth of the Indian cutting industry during the 1980s due, in large part, to the development of the Argyle lamproite deposit.
1991	- Announcement of gem grade diamond-bearing kimberlite pipes at Lac de Gras, central NWT, Canada. The discovery was made by Canadian geologist, Charles Fipke.
1992	- South Africa's tenth pipe deposit (Venetia) under development and Russia's seventh pipe deposit (Jubilee) undergoing testing. Venetia reached full production at the end of 1992.
1993	- **BHP Minerals - Dia Met Minerals** and **Kennecott Canada - DHK Resources** file applications for permits and licenses to perform bulk sample testing of diamond-bearing pipes at Lac de Gras, NWT, Canada.

VARIABILITY OF DIAMONDS

ROUGH STONES

Diamonds can vary from black lumps to stones as clear as water. In the broadest sense, a diamond can be classified as either industrial, near-gem or gem.[12] All uncut diamond stones are referred to as "rough". The value of rough varies from less than US$1 per carat for grit-sized industrial diamonds to US$1000 or more per carat for large gem grade stones. Near-gem and gem quality diamond stones are also called "cuttable". The near-gem category was introduced perhaps 15 years ago and is used to classify cuttable stones of poorer quality and value.

The major factors for valuing rough diamonds are colour, clarity, weight, presence of mineral inclusions and crystal shape.[13] The majority of natural diamonds have a yellowish or brownish tinge. Diamonds can have different colours but the rarest, by far, are stones with strong colours, such as violet, blue, green, red or pink. These stones command the highest prices of all diamonds. A natural diamond usually contains mineral inclusions. An inclusion is often a grain of some mineral other than diamond, small cleavages called "feathers" or even another diamond crystal of different orientation and colour. The size, shape and extent of the inclusion affects the ease of cutting and the value of the stone.[14] An uncut stone of gem quality will lose 50 to 85% of its weight when cut and polished down to exact faces called "facets". A stone of near-gem quality may be reduced to less than 20% of its original size. An inclusion visible to the naked eye may result in an uncut diamond crystal being sorted into the near-gem category, especially with smaller stones. If all other factors are equal, the crystal shape of a rough diamond is probably its most important criteria because of weight loss considerations during cutting and polishing.

Rough diamonds recovered by mining world-wide are sorted individually by the classification guidelines developed over the years by the Central Selling Organization (CSO), the marketing arm of **De Beers**. There are now over 5,000 classifications[15] for natural diamonds, due to the extreme variability in quality of the individual diamond crystals and the discriminating demands of the diamond jewellery market.

Sorting of rough diamonds is sometimes done electronically by specially developed equipment, but mainly by hand and trained eye.[16] The stones are first sieved and separated by size. They are then sorted into a half dozen or more basic shapes. Some shapes can be sawn by a small diamond saw or laser cutter while other shapes must be cleaved by hand-tools. The stones are then sorted into different qualities such as clarity (5 types) and colour (5+ categories with many sub-categories). Near-gem diamond is sorted into three categories with sub-categories. Frosted (or coated) stones are sorted separately because their interiors cannot be immediately seen.

POLISHED GOODS

Cut and polished diamonds are sometimes referred to as "polished goods" in the diamond trade. Each diamond is classified in accordance with what the retail jewellery trade calls the "4 C's"; Cut, Colour, Clarity and Caratage (weight). The colour and the absence of imperfections in the cut and polished diamonds are the important factors as the white to colourless, flawless gemstones of the "Ideal" cut command the highest retail prices of all gemstones destined to be set into diamond rings. A flawless diamond, by definition, has no internal and external flaws or blemishes discernible to the trained eye under illumination against a dark background and at least 10 power binocular magnification. Jewellery trade associations in various countries have their own diamond rating systems resulting in a multitude of trade-names for polished goods. Colour, in particular, has numerous labels. The most universally accepted scheme seems to be the Gemological Institute of America (GIA) system.

GIA Colour Grading And Purity Standards For Polished Goods[17]

Colour		Purity	
D	Colourless	Fl	Flawless
E	Finest or exceptional white	IF	Internally Flawless
F-G	Fine or rare white	VVS1-2	Very, Very Small Inclusion(s)
H	White	VS1-2	Very Small Inclusion(s)
I-J	Slightly tinted white	SI1-2	Small Inclusion(s)
K-L	Tinted white	I1-3	Inclusions
M-N	Slightly yellowish		
O-R	Tinted yellowish		
S-Z	Yellow		

Jewellers generally use D through K for colour; IF through I1 for purity or clarity

The larger, flawless and very expensive stones are extremely scarce. Some 5,000 absolutely flawless and colourless stones are found each year that are greater than 1/2 carat in finished size.[18] Up to 100,000 tonnes of diamond-bearing material may be processed in order to recover a diamond crystal from which a flawless one carat gemstone may be cut. This is the same as digging up two miles of the gravel highway between Edzo and Fort Providence to find a diamond crystal the size of a small blueberry.

Certain gem quality diamonds with deep colours, called "fancies", and gem quality diamonds weighing 10.8 carats or more are separated out and sold individually to the trade.[19] If industrial diamonds are the everyday "workhorses" of the diamond world, then fancies and large gemstones are the extremely expensive "racehorses". The highest auction price ever paid for a coloured diamond was US$926,315 per carat for a 0.95 carat, cut and polished, purplish-red diamond in 1987. The world record price for a colourless diamond was US$142,232 per carat paid for a 52.59 carat rectangular cut gemstone in 1988. The highest price ever paid for a cut and polished gem was almost US$13 million for the 101.84 carat "Mouawad Splendor" in 1990.

DIAMOND - INDUSTRIAL

Perhaps two-thirds of all natural diamonds ever mined are too flawed or simply too small to be cut and polished into jewels. Called industrial diamond, it is sold to meet a high, continual demand from manufacturing and industry. Since 1870, mining operations have recovered more than 1.5 billion carats of industrial diamonds which have been consumed by the world's manufacturers.[20] The major producers are large operations in Zaire and Australia that recover diamonds of very low gem qualities. Industrial diamond is considered to be a strategic mineral and stockpiled by some governments.

Nearly all manufactured goods used by people today have been touched by diamonds. Diamonds shape the tools that, in turn, make the appliances and machines of modern society.[21] Diamonds in a grit or powder form will cut, grind and sharpen carbide steel. Industrial diamonds have many other applications in addition to abrasive purposes. Drill bits faced with industrial diamonds will core through rock. The metal filament in a light bulb is drawn while still red-hot through a diamond-edged cutter.

SYNTHETIC DIAMOND

Almost 90% of the estimated US$600 million[22] per year demand for industrial diamond is met by "synthetics": diamond manufactured artificially using diverse methods. Several countries have mastered this complex technology and the market is intensely competitive.

Most synthetic diamond is in the form of abrasive grits and powders, but there are larger single crystal and polycrystalline varieties available, depending upon the application. Synthetics have a predictable size and shape that is often preferred over natural stones by the consumers of industrial diamonds. The most common production technology uses ultra-high pressure and temperature to transform carbon to diamond and was invented by Swedish scientists of the **Asea Company** in the early 1950s. This was followed by a **General Electric** patent in 1955. **De Beers** successfully produced synthetic diamonds in 1958 using a different method.[23]

Synthesised diamonds are almost invariably a yellow colour from the nitrogen content and have metallic inclusions caused by the solvents used in the process, making them unsuitable for use in jewellery. Synthesised material can be distinguished from natural diamond in several ways, using well established scientific techniques. The largest industrial synthetic produced to date was manufactured by **De Beers** in 1993 and weighed 35 carats.[24] It was the result of an experiment that took technology and equipment to current limits. However, it is thought that the maximum commercially viable size is two to four carat crystals, which are sawn into plates for incorporation into a variety of tools.

Research into diamond synthesis continues at laboratories owned by **De Beers**, **General Electric**, Japanese **Sumitumo Electric Industries** and others.[25] The technology has not reached the stage where gem grade diamond can be commercially produced.

Low pressure processes such as chemical vapour deposition may well produce the next industrial diamond wonder and a number of organizations internationally are active in this field. The unique electrical, thermal conductivity, hardness and optical properties of diamond make film produced by this method ideal for advanced and active electronics. Diamond film is anticipated as a replacement for the silicon chip by the electronics industry.[26]

Industrial diamond, both synthetic and natural, make up 85% by weight of all diamond sold annually. But at an average price of US$1 to $2 per carat, industrial diamond accounts for less than 15% of the value of all rough diamond.[27] Manufacturers of synthetic diamond must compete with other, inexpensive natural and man-made abrasives.

CUTTING AND POLISHING OF DIAMONDS

"Only diamond will cut diamond."

Anonymous

There is a large number of diamond cutting facilities employing approximately three-quarters of a million workers around the world. There are three, very competitive levels within the world's diamond cutting industry:[28]

1. great numbers of low-wage, but often well-skilled and well-equipped workers polishing gem and near-gem diamonds in facilities throughout Asia, particularly India,
2. mechanized cutting factories that cut and polish small gem diamonds of higher average price in the more industrialized countries, such as Belgium, Israel and Russia, and
3. highly trained individuals or firms that fashion the larger, scarcer and very expensive diamond gemstones in large financial centres, such as New York and London, as well as in the older, established cutting centres.

Major Diamond Cutting Centres of the World [29]

City and/or Country	# of Workers (1990-1991)	Particulars
Bombay, India	700,000	Near-gem, gem; small-sized
Russia	10,000+	Gem; all sizes
Tel Aviv, Israel	10,000	Gem; small to medium-sized
Thailand	8,000	Gem, near-gem; fancies; medium-sized
China	6,000+	Near-gem, gem
Antwerp, Belgium	4,000	Gem, fancies; Major diamond financing centre
South Africa	3,000+	Gem
Sri Lanka	3,000+	Near-gem
Rio de Janeiro, Brazil	2,000	Gem
New York, USA	500	Gem, fancies
Other		
Far Eastern countries	2,500	Near-gem, gem
European countries	<1,000?	Gem, fancies
Hong Kong		Major diamond trading centre and diamond jewellery manufacturing

For the past century, the Indian diamond cutting trade has specialized in reducing the much cheaper near-gem rough diamonds into minute to small gemstones. Near-gem diamonds are referred to as "Indian goods" in the literature published prior to the last decade. In the past, small shops, hand tools, very little automation and low wages relative to the rest of the world were the trademarks of the Indian diamond cutting industry. Supplied by the Argyle lamproite deposit in Australia with its large recoveries of very small (0.03 carat or 3 point median size)[30] near-gem diamonds, the number of low-wage diamond cutters in India increased by perhaps half a million workers during the 1980s. The demand in North America for lower-priced, multiple-diamond jewellery enabled the Indian diamond marketing industry to expand tremendously at this time.[31] Today, the majority of small gem diamond destined for diamond jewellery is cut and polished in India.[32]

Some diamond-producing countries, such as Russia and, until recently, South Africa, have set up cutting factories through government intervention (be it legislation, negotiation or incentive) that withholds a percentage of the rough diamonds mined within the respective country.[33] Elsewhere, such as in South America, some cutting factories are supplied by the diamonds produced by independent alluvial miners and mining companies. Many attempts by independents over the years to start cutting facilities have failed because of difficulty in securing a steady supply of diamonds and their inability to compete successfully against the skills and cost structures in established centres.

DIAMOND - GEMSTONE

Diamonds are prized as the most precious of gemstones. An aura of mystique surrounds diamonds as a result of mankind's age-long fascination with famous gemstones coupled with the effective advertising and strong marketing by **De Beers** during the past fifty years. The tradition of the diamond ring was developed during the past century. People in many countries buy diamonds as the symbol of love and marriage. Several hundred million carats of cut and polished gemstones have been sold to the public since 1870.[34]

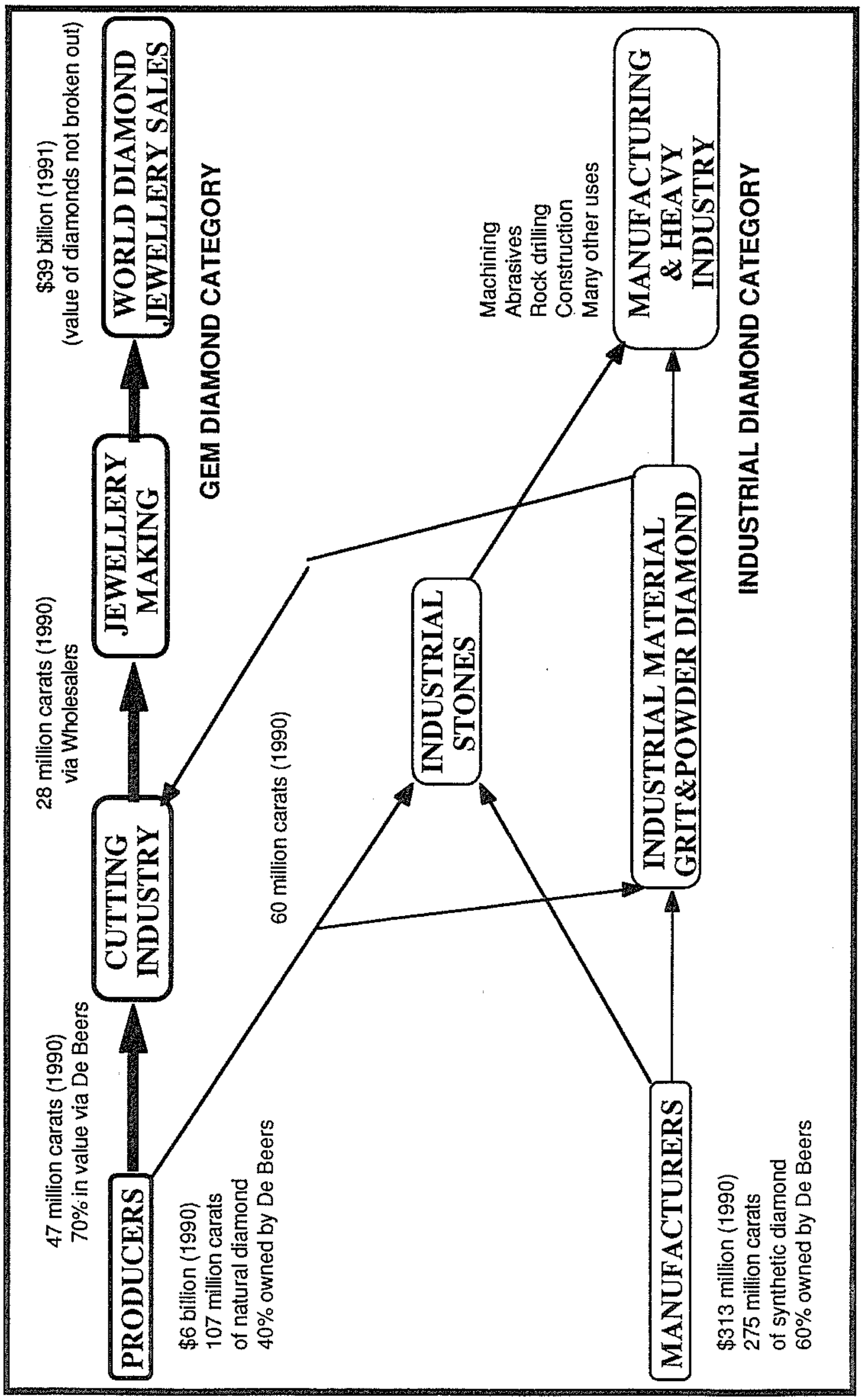
Today, some 40 to 50 million carats of rough gem diamonds yearly flows to mechanized cutting factories or into the hands of low-wage cutters. The mainstay of natural diamond as a commodity is the recovery and sale of rough gem grade diamonds less than one carat in size, which will be fashioned into cut and polished gemstones less than a half carat in finished size. Gem diamond is worth at least ten times more per carat than near-gem diamond, and near-gem diamond, in turn, is worth ten times more per carat than industrial diamond.[35]

Natural gem diamond is certainly one of the most expensive commodities in the world. In terms of dollar value of yearly production, diamond ranked seventh in the world for 1992-93 after copper, gold, aluminum, iron ore, zinc and nickel.[36] During 1990, an estimated US$6 billion of rough gem and near-gem diamond was sold worldwide. For 1991, world diamond jewellery sales totalled US$39 billion.[37]

Comparison Of Some Mineral Commodities

Commodity	Price per Pound	Amount of Ore
Copper (1993)*	$0.92	1/10 ton at 0.5% grade
Gold (1993)*	$4,224	40 tons at 0.3 troy ounces/ton grade
*1993 first half year avg prices, London Daily Metal Prices[38]		
Rough Diamonds	$226,800	5000 to 10,000 tons
Small, gem grade @ US$100/carat [1989 prices] [39]		
Polished Goods	$2,653,560 - $13,018,320	
Half carat size, retail price range from I1 to IF categories [Feb 16/93] [40]		

Diamonds are very transportable. From the minesite, a rough, gem quality stone will be globe-trotting for several years before it is sold as a diamond ring.[41] The uncut stone may be traded in London, England. It may be cut and polished in Bombay, India; Tel Aviv, Israel; Antwerp, Belgium; or several other places. The cut and polished gemstone can be set into jewellery anywhere in the world and, finally, retailed somewhere else entirely. This is called the diamond "pipeline" (Figure 1).



DIAMONDS AND THE NWT, CANADA FIGURE 1 EMPR-GNWT (1993)

MARKETING OF DIAMONDS

"Whether this measure of control amounts to a monopoly I would not know, but if it does, it is certainly a monopoly of a most unusual kind. There is no one concerned with diamonds whether as producer, dealer, cutter, jeweller or customer, who does not benefit from it. It protects not only the shareholders of diamond companies, but also the miners they employ and the communities that are dependent on their operations."[42]

A group of about 80 companies[43], many of international stature, form what is known in popular literature as the "diamond cartel" or the "syndicate". The major marketing force within the diamond industry is the CSO, established in 1930 by **De Beers**, whereas **De Beers** was incorporated in 1888 by a small group of individuals in South Africa and England determined to organize the mining of diamonds in Africa. **De Beers** and its largest single shareholder and sister company, **Anglo-American Corporation of South Africa**, today comprise one of the largest mining groups in the world. Significant shareholdings in both are owned by the Oppenheimer family of South Africa. **De Beers** operates 40% of the world's kimberlite pipe mines, alluvial deposits and beach deposits, as well as producing 60% of the synthetic diamonds manufactured in the Western World. The CSO sells 70% in value of the world's supply of rough gem and near-gem diamonds to the cutting industry.[44]

Through its various agencies, the CSO buys diamonds from the producers and sells them to the cutting industry. The CSO refers to itself as a "producers cooperative".[45] By agreements with the world's major producers, the CSO markets all significant production of diamonds whether mined by **De Beers** or independently. Incoming stones are sorted and assigned values by reference to the CSO's selling assortment. Rough gem diamonds are distributed at sales, called "sights", held in London, England; Lucerne, Switzerland and Johannesburg, South Africa. In 1990, the CSO sold more than US$4 billion worth of uncut diamonds to approximately 160 select buyers called "sightholders".[46] Sightholders are manufacturers or traders who sell to manufacturers who cut and polish gemstones. The polished goods are then sold to jewellery manufacturers.

Equating the supply and demand for gem diamonds has always been a difficult chore for financial analysts.[47,48,49] The commodity of diamond requires a greater knowledge of its mining and marketing parameters than that of other commodities, such as zinc. The majority of the published literature on diamonds is in the fields of physical or material science, geology, exploration and the jewellery trade. The technical information is often estimated or unavailable, particularly when the economic aspects of mining and marketing are approached. A direct correlation for the supply and demand of rough diamonds is not available, as the production figures for the major mines are reported in carats and not dollars, while sales by the CSO are reported in dollars and not carats.

CSO Selling Assortment [50]

Master Sample	Official Producer Sample	Working Sample
The complete reference to all known varieties of natural diamonds with an example stone for each of over 5,000 classifications, that supports, in turn, the proprietary "Price Book", by which the CSO's 600 sorters in London will sort and value all incoming diamonds.	The minesite or producer's sorting centre's reference with the 100's to 1000's of classifications particular to the deposit derived from the diamonds recovered by bulk sampling and ongoing mining.	Smaller sample that a sorter or government evaluator refers to.

The "Sights" As Conducted By The Diamond Trading Company [51]

1. Sights take place ten times a year.
2. Sights take place simultaneously in London, Lucerne and Johannesburg.
3. Buyers are known as "Sightholders" and are able to regularly purchase a significant value of rough diamond.
4. There are six Diamond Trading Company (DTC) brokers, each of which is used by Sightholders to assist them in representing their needs to the DTC.
5. Payment is in US dollars cash within seven days of the date of sale of goods: default on the part of the purchaser may lead to the cancellation of the sale.
6. The DTC reserves the right to cancel a contract of sale, subject to the buyer or the broker being notified within two working days of payment being received.
7. The risk of delivery passes from the company to the customer upon safe delivery of the goods to a carrier.
8. The Sightholder has 14 days following receipt of the goods to lodge any claim against the DTC.
9. The contract of sale is governed by the laws of England.

Gem diamonds have been a stable and very profitable commodity for over a century. **De Beers** has necessarily survived recessions, times of oversupply, the Great Depression, two World Wars and political strife by stockpiling its production of rough diamond, by reducing throughput at its operations and by shutting down its diamond mines for up to several years.[52] The CSO has contended with an ever-increasing supply of natural diamond; the invention, commercial production and marketing of synthetic diamond; and a little-mentioned ongoing conflict with United States' anti-trust government agencies.[53]

The present major natural diamond producers have been spared the boom-and-bust cycles prevalent to mining. The CSO annually buys about US$1 billion worth of rough gem diamonds out of the 10 to 15 million carats recovered yearly since the early 1960s at Yakutia, Russia. The CSO negotiated a five year, US$5 billion sale-and-loan deal with Russia in 1990.[54] Today, the CSO buys 95% of the rough gem diamond production of the Republic of Sakha, part of the Russian Federation.[55] Botswana has profited greatly from diamond mining with an annual cash flow said to be greater than US$1 billion since the early 1970s. The marketing of rough diamonds outside of the CSO's channel has been supported intermittently by production from large alluvial operations and one hardrock mine in Zaire (that recovers mostly industrial quality diamonds) as well as production from gem diamond alluvial fields in western Africa and South America.

1989 PRICES FOR ROUGH DIAMONDS SOLD BY THE CSO [56]

Categories	Prices (US$/carat)
Large Gems (>2 carats)	600-800+
Medium Gems (>0.45-2 carats)	200-300
Small Gems (<0.45 carat)	50-150
Near-Gem	5-150
Industrial Stones	5-150
Industrial Material	1-2
Synthetic Diamond	0.20-125

The CSO has managed to accommodate huge increases in diamond supply resulting from the development of three new mining regions since 1960, all the while achieving increased sale prices for rough diamonds. In 1970, the world diamond mining industry recovered 42 million carats of diamond that was classified as 25% gem and 75% industrial. The introduction of the near-gem category during the late 1970s and early 1980s meant that up to 40% more of the world's annual supply of diamonds flowed to the jewellery trade rather than being consumed as industrial diamond. In 1990, world production was 2.4 times greater than 1970, and consisted of 15% gem, 38% near-gem and 47% industrial diamond.[57] Despite the tremendous increases in the amounts of rough diamond recovered annually since the 1960s, the amount of flawless rough gem diamonds sold has not changed appreciably.[58]

"Good stones are relatively scarce - around 10 per cent of the market by volume accounts for over 50 per cent of the market by value." [59]

The introduction of the near-gem category during the 1980s is largely due to the development of Australia's Argyle diamond mine. This last huge increase in production, coupled with the adoption of the near-gem classification by all the world's producers has resulted in a substantial growth of the rough gem and near-gem diamond stockpile held by the CSO. The annual reports of **De Beers** show the value of the stockpile has climbed steadily from US$0.5 billion in 1979 to US$3.034 billion in 1991. The value of diamonds stockpiled by the CSO has approached the value of their yearly sales.[60]

1993 JEWELLERY WHOLESALE PRICES FOR POLISHED GOODS [61]	
Weight (carats)	Price Range For All Grades (US$/carat)
3	3,560 - 35,700
1	2,240 - 13,900
1/2	1,170 - 5,760

Spearheaded by its famous "A Diamond Is Forever" slogan, **De Beers** has developed the world's most effective advertising campaign. Today, between 70% and 80% of Western brides receive diamonds. **De Beers** charts the gem diamond market worldwide to gauge its sales of rough gem diamonds and to promote new markets for diamond jewellery. The CSO maintains contacts with governments and monitors trade in producing countries. The three basic points of a recent Russian marketing program bear repeating:

> **"•De Beers protects Russian diamond resources by maintaining a stable market.**
> **•De Beers will buy most of the diamond production regardless of market conditions.**
> **•De Beers spends $157 million yearly to advertise diamond jewellery around the world."** [62]

The CSO reported record sales of rough diamonds and a drop of US$500 million in their stockpile[63] for the first half year of 1993 after several years of reduced sales and cutbacks in producer quota purchases. It appears to be "business as usual" for **De Beers**, who **"remain cautiously optimistic about the future"**.[64]

> **"We shall continue to fulfil, for as long as is necessary, our traditional role of stabilising the diamond market in the interests of all."** [65]

GEOLOGY OF DIAMOND DEPOSITS

Natural diamonds are primarily associated with a rock called kimberlite. Most diamonds have been mined from deposits called kimberlite pipes. A few diamonds have been found in meteorites, some metamorphic rocks subjected to very high pressures and some Precambrian conglomeratic rocks which are the ancient equivalents to modern-day river systems. Numerous diamonds have been found in the gravel of many rivers and along one stretch of beach and offshore deposits on the west coast of southern Africa. These are often referred to as secondary deposits. The majority of diamonds have been recovered from igneous rocks called kimberlite and lamproite. Economic diamond-bearing "hardrock" or primary deposits are composed of kimberlite and, in one case, lamproite.[66]

Diamonds were once believed to have crystallised within the kimberlite in which they were found. Studies have shown this not to be the case. Kimberlite, host rock to diamonds, is the transportation system and not the actual source rock in which diamonds are formed. The diamond crystals are usually much older, and in some cases, they have been determined to be as much as 2.9 billion years older than the host kimberlite pipe.[67,68] Diamonds are formed in rocks called peridotite or eclogite 150 km or more below the Earth's surface. The kimberlite eruption carries "xenoliths" or rock fragments of diamond-bearing eclogite or peridotite to the surface (Figure 2). Many of the rock fragments break apart during the rapid ascent, releasing diamond crystals into the kimberlite. The speed at which a kimberlite ascends is estimated to be 20 or 30 km per hour.[69] The temperature of the kimberlite must be low enough and the rate of ascent fast enough to prevent the oxidation (burning) and the resorption (dissolving) of the diamonds while the transporting igneous "melt" ascends to the Earth's surface.

Kimberlites form carrot-shaped or ice cream cone-shaped vertical orebodies at the Earth's surface called "pipes".[70] There are three parts to a kimberlite pipe: a crater zone near the surface, a diatreme zone which consists of the main part of the deposit and a root zone below the main part (Figure 3). The typical deposit is partly eroded and often lacks the crater zone. Near the surface, a pipe can measure up to 500 metres or more across, depending on the level of erosion. The surface areas of economic pipes range from less than 1 to 146 hectares, and average 12 hectares (30 acres).[71] The sides of the pipe slope slightly inwards. One or two kilometres underground, the pipe will have shrunk to an irregular root zone, which can measure up to 200 to 300 metres in width and up to 500 metres in vertical extent.[72]

An understanding of the gaseous nature of kimberlite is required to appreciate its mechanisms of diamond collection, ascent and emplacement. The melt coming up from depth is extremely gas-charged.[73] Abundant gas and fluid are believed to exist in the Earth's crust and at the boundary between the mantle and the deep keels of the continents.[74] There are several kinds of gas-charged igneous rocks that form explosive occurrences or "diatremes" around the world.[75,76]

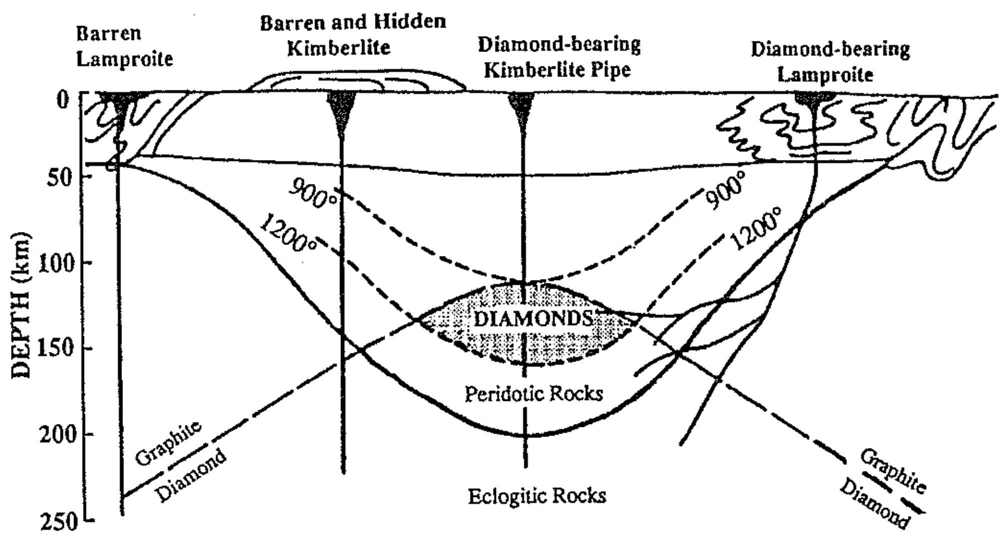
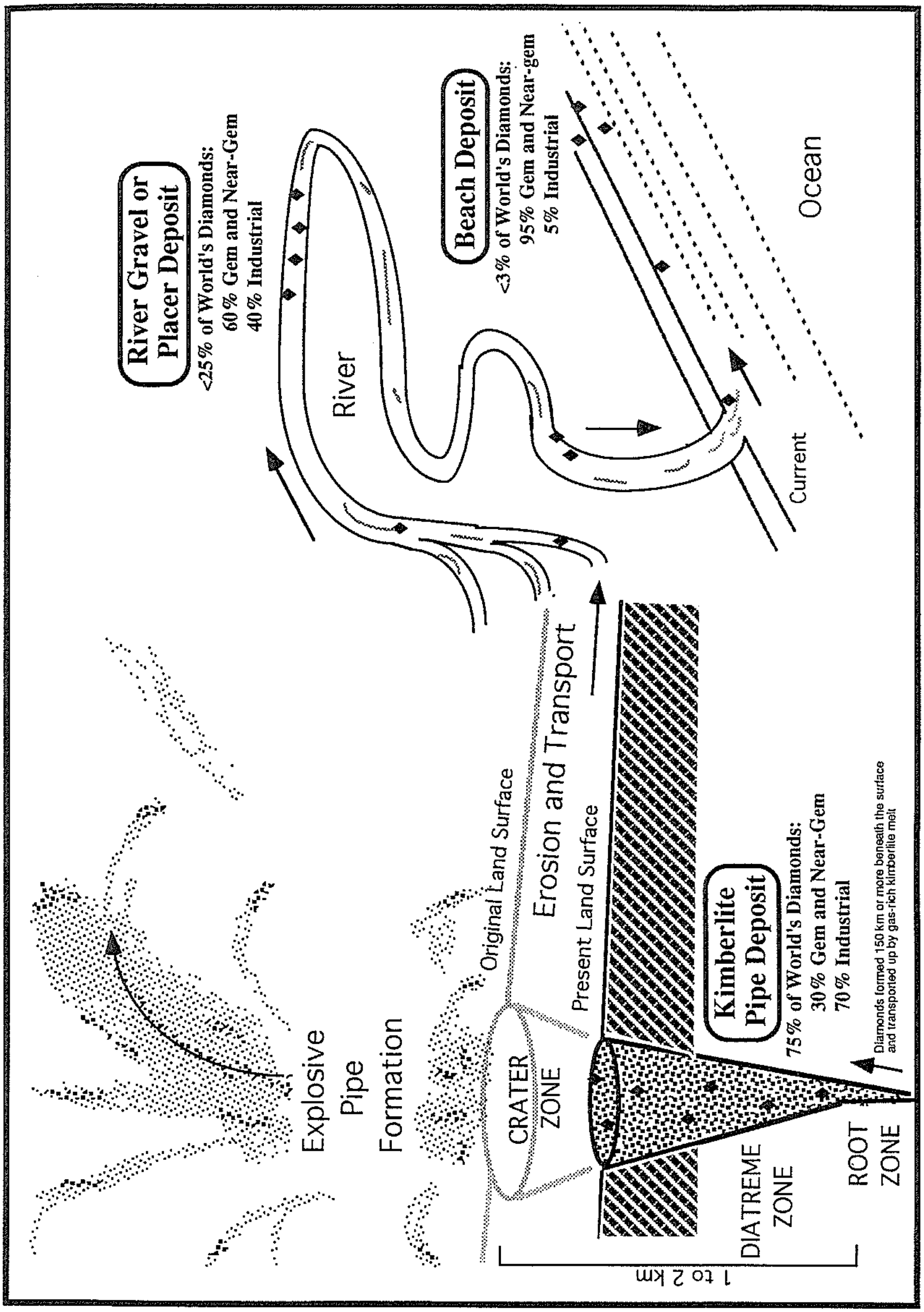


FIGURE 2 Diamond Genesis Model
[modified from Haggerty (1986)]
This model shows a Precambrian Shield in cross-section which can be up to 200 or more km thick. The oldest part of a Shield is bounded by younger, deformed Precambrian rocks called "mobile belts" which are represented by folded lines. The dashed lines are "isotherms" or lines connecting points of equal temperature. Carbon at high pressure will form graphite or diamond depending on the temperature. The dashed lines may move up or down depending on the relative temperatures of the "cold" crust and "hot" mantle over time. The shaded area is the "storage area" where diamonds can form. Peridotitic (P) and eclogitic (E) rocks are two types of boulders brought up by a kimberlite pipe or lamproite deposit. Natural diamond can be divided into "P-type" and "E-type" categories. So in this example, the central, exposed kimberlite pipe contains eclogitic boulders, diamond-bearing peridotitic boulders and P-type diamond.

NATURAL DIAMONDS FROM PIPE TO SEA



DIAMONDS AND THE NWT FIGURE 3 EMPR-GNWT (1993)

The ascending kimberlite melt can be compared to a well-shaken soda pop. Uncork the cap from the bottle and bubbles plus soda rush up. A mixture of rock fragments, liquid rock and gas ascends through the crust and explosively erupts like a giant geyser at the Earth's surface. At a depth of several kilometres below the surface, the melt encounters ground water which explosively boils when in contact with a hot igneous melt. Thereafter, the melt explosively widens its path to form the near-surface pipe deposit. The pipe breaks through ground level and vents gas and material, only to slump back and plug itself up.

The diatreme zone contains an assortment of the different rocks that the kimberlite breaks through while en route to the surface, providing geologists with a snapshot picture of the Earth's crust taken at the time of the pipe's formation. Even boulders and fossils from rocks that are now eroded completely away are sometimes found towards the top of the pipe, preserved in the material that slumped back into the pipe.

Diamond content is not uniform throughout a diamond-bearing pipe. The diamond content can vary both horizontally and vertically from nil to economic concentrations. Pipes may have several discrete phases.[78] Each phase has a different mineralogy and diamond concentration. Diamond concentration also appears to decrease with depth in a pipe.[79]

Kimberlite consists mainly of the mineral olivine[80,81] which alters to serpentine, a common constituent of carvingstones in the NWT. Kimberlite has very little quartz, radioactive minerals or base metal sulphides. On a freshly broken surface, kimberlite is commonly a mixture of dark-coloured minerals of variable grain sizes. It may have a dark greenish to bluish colour overall, and is called "blue ground" in South Africa.[82]

Minerals Of Kimberlite[83]

Groundmass or Matrix

- Olivine
- Mica (Phlogopite)
- Carbonate (Calcite)
- Serpentine
- Clinopyroxene
- Monticellite

And accessory minerals

- Apatite
- Ilmenite
- Spinel (several kinds)
- Perovskite

Macrocrysts (rounded grains or minerals derived, in part, from the Earth's mantle)

Any of

- Olivine (major constituent)
- And accessory amounts of
  - Phlogopite
  - Picroilmenite*
- Diamond (rarest constituent, often not present)
- Chrome Spinel*
- Garnet (Pyrope)*
- Chromite*
- Orthopyroxene (Enstatite)

Xenoliths or Rock Fragments

- Peridotite (may contain diamond)
- Eclogite (may contain diamond)
- Others

*diamond indicator minerals

Also derived in part from Clement et al (1984) and Mitchell (1989)

Kimberlite rock exposed to air and water will decompose, a process that earth scientists call "weathering". It will be turned, in part, into clay or what is called "yellow ground" in South Africa.[84] If left undisturbed or not eroded away, the top of a kimberlite pipe may alter to a clay-rich cap up to a hundred metres thick in a tropical climate or, perhaps, tens of metres thick in a polar environment. There is often a higher recovery of diamonds from "yellow ground" compared to the underlying, unweathered "blue ground".

The weathering of kimberlite pipes leads to erosion. The diamonds released are transported and concentrated by water into secondary deposits. Information about diamond deposits of the South African Precambrian Shield indicate that economic pipe deposits have about a 30% gem ratio, the alluvial deposits have about a 60% gem ratio, while the beach and offshore mining operations at Namibia have a 95% gem ratio (Figure 3).[85] The erosion and transport of diamonds purifies the gem grade of placer deposits in a downstream or down-ocean current direction by knocking apart the imperfect, industrial grade stones.

Pipes vary in age but they are generally much younger than the several billion year old rocks that they are in contact with at or near the Earth's surface. Age-dating studies show that economic kimberlite pipes range in age from 52 million years old (Mwadui pipe) to over a billion years old (Premier pipe).[86] There seems to have been from three to five worldwide periods of pipe formation during the past several billion years.[87]

There are an estimated 5000 occurrences of kimberlite in the world, including pipes, small dikes, sills, veins and assorted blowouts.[88] There are about 1000 pipes ranging from less than 1 hectare to more than 150 hectares in surface area. Kimberlites have been found on every continent except Antarctica and on a number of sub-continents including India and Greenland. Diamond-bearing kimberlite pipe mines are restricted to the very old Precambrian Shield portions of continents and sub-continents or what geologists call "cratons" (Figure 4). Kimberlite pipes and occurrences are found in "clusters".[89] Clusters can be described as "shotgun blast patterns" coming from below. There are over 800 occurrences in southern Africa[90] and 800 in Siberia,[91] the two Precambrian Shields best explored for diamonds. The world's largest Precambrian Shield is in North America, most of which is less explored for diamonds than the Precambrian Shields of southern Africa and Siberian Russia.

EXPLORING FOR DIAMONDS

A kimberlite pipe is not easy to find. Regionally, a pipe is a small target that is less than 500 metres across and rarely exposed, as kimberlite minerals are generally softer than the harder quartz-rich rocks the pipe intrudes. The top of the pipe may have been altered by weathering, in part, into clay. The search for a kimberlite pipe requires expensive, technical exploration methods rather than simple prospecting. However, exploration techniques such as heavy mineral sampling and airborne geophysical surveying have advanced to the point where a kimberlite pipe can be discovered once attention has been focused on a region. Nevertheless, there is no guarantee that the discovery will contain even a single diamond.

HEAVY MINERAL SAMPLING

A heavy mineral sampling program tests for hard, dense, distinctive mineral grains eroded and transported away by water or ice from a kimberlite pipe. Kimberlite contains perhaps 0.1% or more of certain specific "indicator minerals",[92] namely, pyrope garnet, chrome diopside, picroilmenite and chromite. Not all of these indicator minerals are present in every kimberlite occurrence. The low calcium, chrome-pyrope variety[93] of garnet (also called "G10" garnet) signals the presence of mantle-derived xenoliths indicative, in turn, of a possible diamond-bearing pipe.[94] While diamond itself meets all the easy-to-identify criteria, it is rarely abundant enough to be a useful indicator mineral. A "rich" pipe or placer deposit contains just 0.00002% diamond content.

Indicator Mineral Characteristics[95,96]

Mineral	Colour	Grain Size	SG*	Comments
Pyrope Garnet	Purple - Red	Up to 15 cm	3.6	Magnesium-rich variety
Picroilmenite	Grey	Up to 10 cm	4.7	Glossy, opaque, magnesium-rich variety
Chrome Diopside	Bright Green	Up to 1 cm(?)	3.2	
Chromite	Orange - Red	0.1 - 0.5 mm	4.6	Rounded, transparent crystals

* SG denotes Specific Gravity

Sampling programs test stream, beach or glacial gravel, sand and clay for indicator minerals. Glacial material in the NWT most often takes the form of "till" and "eskers". Till is the thin, uneven blanket of clay, sand and boulders deposited on top of the rocks of the Canadian Shield. Eskers are sinuous sand and gravel deposits formed by rivers that ran underneath the ice when the continental glaciers melted. Samples, whether rock or dirt, are processed to separate out the heavier minerals. The heavy mineral concentrate is examined microscopically. A sampling program attempts to trace indicator minerals upstream or "up-ice" to a kimberlite pipe. Where the indicator minerals disappear from the sampled material, the explorationists know that they have passed by the pipe. As the majority of pipes are hidden under overburden, other methods must then be employed to locate the target.

GEOPHYSICS

Geophysics, the application of physics to geology, is used to examine the measurable properties (magnetism, gravity, conductivity, radioactivity) of rocks. Geophysicists can "look" through overburden into the rocks to a depth of several hundred metres below the surface. Geophysical instruments detect subtle differences in electrical conductance and magnetism between the kimberlite pipe and the surrounding country rocks. A kimberlite pipe is often, but not always, weakly magnetic. A pipe, if it has a clay-rich capping, will conduct electricity better than the surrounding rocks of the Precambrian Shield. An airborne geophysical survey flown by fixed wing aircraft or helicopter will quickly evaluate a large area and locate targets with suitable geophysical responses.

EXPLORATION LEADING TO DEVELOPMENT

A general exploration format has evolved for the NWT diamond play. Regional-scale esker and till sampling, in combination with airborne magnetic and electrical geophysical surveying, are being employed. Targets are selected from the combined results and tested by diamond drilling to see if each is a kimberlite pipe. Core samples from diamond drilling programs range from ten to hundreds of kilograms. If the sampling of drill core indicates a high concentration of diamonds then larger samples are collected by either a rotary or diamond drilling, yielding samples weighing from 20 to 160 tonnes. Samples containing diamond concentrations from 0.60 to over 1 carat per tonne are considered to be in the economic range. Diamonds collected by these sampling programs are appraised to give a preliminary average dollar value per carat for each pipe tested. Pipes with economic concentrations of diamonds will be further evaluated by "bulk sampling" programs. The bulk sampling programs are essentially the small-scale mining and processing of a minimum of 3,500 tonnes of kimberlite from each pipe.

The evaluation of a diamond-bearing pipe requires large samples because of the very low concentration and the extreme variation in the distribution and quality of natural diamond. In order to be reliably evaluated, a kimberlite pipe is bulk sampled to provide 5,000 to 7,000 carats of diamonds.[97] This may require the mining and processing of up to 20,000 or more tonnes of kimberlite. The diamonds recovered are sorted and appraised according to the CSO selling assortment. Such an evaluation indicates the average dollar value per carat, the average stone size, the gem ratio, the carats per tonne and potential reserves for the deposit. These are the bottom line figures that are required before a production decision can be made.

It Can Take A While To Find A Diamond Mine

Deposit (country)	Exploration (years)	Development (years)	Development Cost (US$)
Mir, USSR	6	5	?
Orapa, Botswana	12	4	?
Argyle, Australia[98]	7	6	$300 million
Venetia, RSA[99]	11	9	$433 million
Lac de Gras, NWT, Canada	11 to date*	--	$50 - 60 million**

*Several major pipe deposits are indicated but not proven for Lac de Gras **Estimated exploration costs to spring, 1993

A typical exploration program culminating in a diamond mine requires an expenditure in the order of $US500 million. It has taken from 11 to 20 years to explore for, discover and develop the large diamond mines that opened during the past two decades.

WORLD DIAMOND MINING MAP

Dashed lines outline the Precambrian Shields older than 2.4 billion years in age

♦ Major diamond pipe mine or region ⊕ Major alluvial diamond field ◊ Undeveloped hardrock deposits with >100,000 carats

Modified from Janse (1985)

DIAMONDS AND THE NWT FIGURE 4 EMPR-GNWT

WORLD DIAMOND MINING

"In so minute a quantity is the gem present that only by the merest chance is it observed *in situ*." 100

Approximately 130 tonnes (144 tons)[101] of rough gem diamond have been recovered during the past 120 years from 24 large hardrock mines and numerous placer operations primarily in southern and western Africa, in Siberian Russia and Australia (Figure 4). The total world diamond mining recovery can be represented by a cube of solid diamond measuring 3.6 metres (11 feet) per side. Placer operations, including small "diggings" worked for years by tens of thousands of individuals in African, South American and other tropical countries, may have yielded 25% of the world's gem diamond production. The supply of natural diamond has increased immensely over the years (Table 1). In 1890, 2.5 million carats were mined in three countries. In 1990, over 100 million carats were recovered from mining operations in 22 countries. During the past 40 years:

1. three new major producing regions have come on-stream with start-up dates spaced 10 years apart: Russia (1960), Botswana (1970) and Australia (1981), and

2. the diamond mining industry essentially changed from gem diamond production dominated by the higher gem grade alluvial deposits to the lower gem ratio, large tonnage pipe deposits.

Producers report total yearly production in carats or by weight. More importantly, the quantity, quality and stone size of the gem grade diamonds determine the revenue from each mining region. In terms of gem diamond production and reserves, Russia and Botswana are comparable to South Africa, while Australia is a producer of mostly industrial diamond and comparable to Zaire (Table 2). Zaire (6% gem grade) has produced the most diamonds of any country in the world with an estimated 718 million carats to 1990, while Australia (5% gem grade) currently leads the world in diamond production with an annual output of 40 million carats. Therefore, Zaire and Australia, while producing the highest volumes of diamonds annually, are in actuality the "poor cousins" in the financial world of gem diamond. South Africa has produced the most gem diamond of any country, while Botswana currently leads the world in value of large gem diamonds produced. Russia is second in both of these high revenue generating categories.

TABLE 1

World Diamond Production From 1870 to 1990

(for the first year of each 20 year period)

COUNTRY (Older Names)	FIRST FOUND	FIRST PRODUCED	% FROM PIPES	THOUSAND CARATS PRODUCED 1870	1890	1910	1930	1950	1970	1990	TOTAL CARATS PRODUCED	COUNTRY
INDIA	1000?	1000?	0	2	nr	nr	nr	nr	20	15	21,000,000	INDIA
BRAZIL	1725	1730	0	200	nr	nr	115	200	300	1,500	47,101,000	BRAZIL
SOUTH AFRICA	1867	1870	80-90	103	2,505	4,807	3,164	1,748	8,112	8,708	446,856,000	SOUTH AFRICA
NAMIBIA (German SW Africa)	1908	1909	0			891	415	488	1,865	761	63,288,000	NAMIBIA
GUYANA (British Guinea)	1890	1921	0			4	110	38	61	8	4,131,000	GUYANA
ZAIRE (Belgian Congo)	1907	1917	10				2,519	10,148	14,087	19,427	718,117,000	ZAIRE
ANGOLA	1912	1921	0				330	539	2,396	1,300	59,800,000	ANGOLA
GHANA (Gold Coast)	1919	1925	0				861	950	2,550	637	100,785,000	GHANA
TANZANIA (Tanganyika)	1910	1945	100				13	165	708	85	18,590,000	TANZANIA
CENTRAL AFRICAN REPUBLIC	1914	1947	0					111	482	381	13,829,000	CAR
GUINEA (French W. Africa)	1932	1950	0					126	74	135	8,865,000	GUINEA
SIERRA LEONE	1930	1935	0					655	1,955	78	52,405,000	SIERRA LEONE
VENEZUALA	1901	1955	0					60	509	333	13,834,000	VENEZUALA
IVORY COAST	1929	1960	0						213	12	5,743,000	IVORY COAST
LIBERIA	1930	1958	0						812	100	18,117,000	LIBERIA
BOTSWANA	1966	1970	100						464	17,352	151,747,000	BOTSWANA
LESOTHO	1958	–	100						17	nr	412,000	LESOTHO
RUSSIA (USSR)	1829	1960	100						7,850	15,000	271,850,000	RUSSIA (USSR)
INDONESIA (Borneo)	1000?	–	0						20	30	1,000,000	INDONESIA
AUSTRALIA	1851	1981	95							34,662	184,061,000	AUSTRALIA
CHINA	1955	?	?							1,000	10,850,000	CHINA
SWAZILAND	1973	–	100							42	327,000	SWAZILAND
OTHERS							3	3	nr	nr	1,167,000	OTHERS
		YEARLY TOTALS:		305	2,505	5,702	7,530	15,232	42,495	101,566	2,213,875,000	

Modified from Levinson et al (1992)

TABLE 2
Natural Diamond Production and Ranking by Country

COUNTRY	Production Totals For 1870 - 1990 (1)	Gem Grade Factor	Total Gem Production In Carats (3)	Ranking: Production Overall (1)	Ranking: Production 1989 (2)	Ranking: Production Overall Gem (3)	Ranking: 1989 Large Gem Value (1)
ANGOLA	59,800,000	0.70	41,860,000	8	7	6	5
AUSTRAILIA	184,061,000	0.15?	27,609,000	4	1		
BOTSWANA	151,747,000	0.30?	45,524,000	5	3	5	1
BRAZIL	47,101,000	0.60?	28,261,000	10			
CENTRAL AFRICAN REPUBLIC	13,829,000	0.20?	2,766,000				
CHINA	10,850,000	0.60?	6,510,000				
GHANA	100,785,000	0.20	20,157,000				
GUINEA	8,865,000	0.93	8,244,000				
GUYANA	4,131,000	0.60?	2,479,000				
INDIA	21,000,000	0.60?	12,600,000				
INDONESIA	1,000,000	0.60?	600,000				
IVORY COAST	5,743,000	0.60?	3,446,000				
LESOTHO	412,000	0.80	330,000				
LIBERIA	18,117,000	0.70?	12,682,000				
NAMIBIA	63,288,000	0.95	60,124,000	7	6	4	4
RUSSIA	271,850,000	0.35?	95,148,000	3	4	2	2
SIERRA LEONE	52,405,000	0.40	20,962,000	9			
SOUTH AFRICA	446,856,000	———	160,686,000	2	5	1	3
		(20% alluvial x 0.60?) + (80% pipe x 0.30?)					
SWAZILAND	327,000	0.30?	98,000				
TANZANIA	18,590,000	0.30?	5,577,000				
VENEZUALA	13,834,000	0.60?	8,300,000				
ZAIRE	718,117,000	0.12?	86,714,000	1	2	3	
OTHERS	1,167,000	0.60?	700,000				
Total	2,213,875,000		651,559,000 CARATS				

(1) Levinson et al (1992)

(2) Harben and Notstaller (1991)

(3) Total Gem Production = (Production) x (Gem Grade Factor)

"Annual diamond production from major operating mines ranges from as little as 0.25 million carats/year (of good quality diamonds) to in excess of 9 million carats. Ore treated from primary deposits ranges from 3 to 7.5 million tons and possibly significantly more in the case of one Russian operation (Udachnaya). The CDM secondary deposit operation on the west coast of Namibia currently treats approximately 20 million tons per year. Grades of primary deposits range from below 10 carats per hundred tons (cpht) to well in excess of 100 cpht. Average diamond revenues range from less than US$10/carat to more than US$150/carat (primary deposits) and are significantly higher at some secondary deposits (notably the alluvial deposits along the west coast of southern Africa). Percentages of gem from primary sources generally range form near zero to 40 - 50%. Many alluvial deposits produce gemstones almost exclusively.
Each of the operating mines is characterised by unique combinations of grades and diamond qualities and significant local variations in grade occur frequently from place to place within individual deposits." 102

Diamond-producing kimberlite pipes occur in clusters that contain an average of 22 pipes of which only one or two may be mines.[103] Kimberlite pipe clusters that contain producers are 40 km wide on average and 350 to 400 km apart in Africa and Siberia.[104] However, Siberia has what should be considered a double cluster while South Africa has a 150 km wide area with three clusters - Kimberley, Koffiefontien and Jagersfontein. The producers tend to be the more central, larger pipes with more than one part or "lobe".

Diamond-Producing Kimberlite Pipe Clusters Of The World*

# of Mines / # of Pipes	Cluster Name	Country
5 / 29	Kimberley	Republic of South Africa
3 / 40	Aikhal	USSR/CIS
2 / 29	Orapa**	Botswana
3 / 11	Mir	USSR/CIS
1 / 56	Udachnaya**	USSR/CIS
1 / 28	Mwadui	Tanzania
1 / 17	Venetia	RSA
1 / 16	Koffiefontein	RSA
1 / 12	Premier	RSA
1 / 9	Jagersfontein	RSA
1 / 7	Jwaneng**	Botswana
1 / 6	Finsch	RSA

World's 24 hardrock diamond mines = above 21 kimberlite pipes + Mbuji Mayi (Zaire) + lamproite- Argyle (Aust.)** + lamproite-Majhgawan (India)

*Modified from Janse (1985) **Deposits with estimated 500 million carats *in situ* (See also Appendix A)

MINING

Diamond pipe mines in South Africa, Russia and Botswana are long term operations, producing diamonds for at least 20 to 50 years or more from reserves worked by open pit or underground bulk mining methods. All kimberlite pipe mines started as open pit mines with about one third of the producers continuing below their pits as underground operations. Because of the vertical nature of the orebodies, some diamond mines have the steepest walls of all the open-pit mines in the world. The "Big Hole" at Kimberley, South Africa, is one of the world's most impressive excavations. Russian open pit operations are up to 400 metres deep with plans to go to a world record 600 metres depth in the Udachnaya open pit mine.[105] Toronto's CN Tower could fit into a 553 metre deep open pit.

Diamond mining remains at the forefront of modern mechanized mining with emphasis on using large equipment and bulk mining techniques. The most recent pipe deposits to reach production are bigger and richer than previous diamond mines, yet they will be mined out more quickly. For example, it took the better part of a century to mine the 50 million tonne deposits at Kimberley, South Africa, whereas the Jwaneng and Orapa pipes of Botswana are at least five times larger and have estimated lifespans of forty years.[106]

The richest diamond mines in the world are the three-lobed Jwaneng pipe in Botswana and the two-lobed Udachnaya pipe in Russia, each with estimated *in situ* reserves in the order of 500 million carats.[107] An industry expert suggested a value of US$74 billion for the Jwaneng deposit.[108]

Recent African And Australian Diamond Mine Data

Deposit	Year Started	Possible Lifespan	Ore Processed (10^6 tonnes/yr)	Diamonds (10^6 carats/yr)	# Employees
Finsch[109]	1965	35+ years	5	5	1600
Orapa[110-112]	1971	40+	7.4	4.5	1700
*Argyle[113,114]	1981	14+	5	35	720
Jwaneng[115]	1982	30+	5	4.5	1500
Venetia[116]	1992	20+	3.3	4	870
(African) Avg.		30+	5	4.5	1400

*Australia's Argyle lamproite deposit excluded from averaging of southern Africa kimberlite pipe deposits.

Diamonds that can be recovered by mining occur in very low concentrations. A one carat per metric tonne grade is considered "rich" for either a hardrock or a placer mine. Therefore, a rich pipe deposit has a diamond to waste ratio of 1:5,000,000. The average grade of diamond mines worldwide may be as low as 0.25 carats per metric tonne.[117], yielding an average ratio of 1:20,000,000. In comparison, a gold mine at a grade of 0.3 troy ounces per ton has an ore to waste ratio of 1:100,000. The content of gold in the ore at a typical gold mine is 50 to 200 times more concentrated than the content of diamonds in kimberlite at a diamond mine. The world's moving-material-for-profit record is held by the beach diamond mining operation at Namibia in southwest Africa which sustains an incredible 1:100,000,000+ ratio.[118]

PROCESSING

The recovery of diamond is accomplished by mechanical, gravity-related methods rather than the chemical leaching processes used for gold or the chemical flotation methods used for base metals. The development of each major mining region has resulted in new processing innovations. Most mines use a combination of various crushing, concentration and collection methods.[119] Up to 15,000 tonnes per day is processed to recover up to 3 kg of diamonds, of which 1 kg may be of gem quality. Generally, tailings finer than 1.5 to 2 mm in particle size are discarded.

The most widely used concentration method is heavy media separation (HMS). A dense pulp made of ferrosilicate or magnetite is mixed with the crushed and sized host material. Diamonds and other heavy minerals fall through while the lighter kimberlite rock and minerals float off the top. A reduction of more than 1000:1 of the host material down to a heavy mineral "concentrate" is typical of HMS.

The HMS concentrate is processed by techniques that make use of the special properties of diamond, its fluorescence when X-rayed and its ability to stick to grease. The concentrate is run through X-ray fluorescence sorters to collect diamonds of larger size as well as over vibrating grease tables to recover finer-sized diamonds. Some mines have non-fluorescent or coated diamonds and do not use X-ray sorters. Other operations have salt- or mineral-coated diamonds and cannot use grease tables.

How An X-Ray Sorter Works[120]

1. Required: a supply of diamond concentrate from a heavy media separation (HMS) plant.
2. A narrow conveyor belt feeds the concentrate into a single particle line. The line of particles fall off the end of conveyor belt to a point where...
3. an X-ray source, a photomultiplier or detection tube and a compressed air jet are focused.
4. The X-rays cause the diamond to fluoresce a light blue colour, and the detector triggers the air jet to puff the diamond out of the line of falling particles.
5. The concentrate in the waste bin is returned to the self-crushing circuit.
6. The rough diamond in the diamond bin, if of gem quality, will eventually become a cut and polished gemstone in a diamond ring.
7. The diamond recovery efficiency of X-ray sorters is said to be greater than 99%.

A deep open pit diamond mine requires the removal of country rock adjacent to the pipe for pit slope stability, resulting in the handling of a volume of waste rock several times more than the amount of processed tailings. The material produced by mining and processing is permanently stored in several areas: a coarse waste rock dump, one or more rock dumps (or stockpiles) of kimberlite considered to be uneconomic, and a predominantly sand- to clay-sized tailings impoundment area. Additionally, there are one or more temporary stockpiles of diamond-bearing kimberlite awaiting processing.

EMPLOYMENT

Employment sections at the Orapa mine in Botswana[121] include: mining, heavy equipment operators, mill processing, utilities (mechanics, electricians, construction, etc.), mine engineering, environmental engineering, surveying, geology, administration, secretarial, diamond sorting, security, training, transportation, aircraft, hospital or first aid, and townsite operation. Diamond sorting performed either at or away from the minesite requires the training of a substantial number of people. When compared to a base metal mine, a diamond minesite requires more people in the milling and security sections. Most of the jobs at a diamond mine are filled by skilled persons with experience, training and an education level of Grade 10-12 or better.

Breakdown Of Jobs At A Large Diamond Mine

Heavy Equipment Operators	200
Mill Operators (includes utilities, shop trades)	300
Management (includes engineering, training, first aid)	200
Other (includes diamond sorters, security, ground and air transportation)	100
(estimated total)	800

PRODUCTION AND REVENUE FROM A LARGE DIAMOND MINE

The recent African and Australian diamond mine data suggest that a large diamond mine, on average, has a lifespan of 30 years, processes 150 million tonnes of kimberlite and recovers 135 million carts of diamonds worth US$13.5 billion (based on an average value of US$100 per carat). The diamond concentration is 0.90 carats per tonne at an estimated 30% gem ratio. Annually, the mine recovers 4.5 million carats of rough diamonds worth US$450 million from 5 million tonnes of ore. Not factored into the calculation is the "bonanza bonus" of diamond mining. A proportion of larger diamond stones of high gem quality is unreservedly a requirement for an economic diamond deposit and can add substantially to a mine's earnings.

NWT Open Pit Deposits Versus A Large Diamond Mine

Type of Mine	# Employees	Tonnes/Day	Tonnes/Year
Base Metal*	250	3,000	1,000,000
Gold**	350	10,000	3,600,000
Diamond***	800	15,000	5,000,000

* Design rate for Izok base metal deposit(NWT) ** Design rate for Colomac gold deposit(NWT)
***Estimated average of Argyle (Australia) and Venetia (South Africa) diamond mines

Using an average value of US$100 per carat, a diamond pipe mining district or singular deposit with a 500 million carat *in situ* reserve is worth US$50 billion. Production plus reserves for the Con and Giant mines at Yellowknife, NWT, total 425,000 kg[122] of gold worth about US$4.8 billion.[123] A topnotch diamond mine or mining region is therefore worth the equivalent in value of product of ten Yellowknife gold mining districts.

FUTURE FOR DIAMONDS

"The danger to the security of the diamond industry is not the discovery of a rich new diamond field, but the irrational exploitation of it." [124]

The future for the commodity of diamond basically depends on the industry's ability to market the supply of gem diamonds. Some assumptions about natural diamond supply to the year 2000 can be made. The 100 million carat level of yearly natural diamond production ought to hold for the remainder of the decade as no new major hardrock deposits are expected to open and no major operating mines are anticipated to close due to depletion. There are four possible scenarios for demand:

1. increase in demand,
2. no substantial change,
3. drastic downscaling, or
4. natural diamond failing as a commodity.

These scenarios, and their potential effects on the diamond industry, are discussed below.

<u>INCREASE IN DEMAND</u>

Due to the present oversupply of cheap small gem and near-gem diamonds, an increase in demand for these stones would not necessarily create the incentive to develop a new mining region. A short-term increase in demand would first be met from stocks of these goods held by the CSO and the producers.[125] One 1992 report **"forecasts global growth in diamond jewellery sales of between 4 and 5 per cent a year over the period 1992-96"**.[126] The Argyle and Jwaneng mines are poised to take advantage of a sustained increase in demand with expansion of their processing facilities anticipated by the mid-1990s.[127] Russian and South African diamond mining regions also have the option of reactivating now-dormant mines.

NO SUBSTANTIAL CHANGE

The real question of "no substantial change" is which country will replace South Africa's production in the long term? Three countries lead the world in value of production of natural gem diamond - Botswana, Russia and South Africa. In terms of age and depletion of deposits, Botswana is young, Russia is mature and South Africa is old. The decline in South Africa's diamond output has been stemmed, in part, by the opening of the Venetia mine.

Countries with less influence in the world of gem diamond are Namibia, Australia and Zaire. Although the Namibian operations recover high quality gem diamonds, they must remove huge volumes of sand and gravel from beaches and ocean bottom with expensive equipment. Zaire and Australia have large reserves of predominantly near-gem quality diamonds. Australia's Argyle mine is facing depletion of delineated reserves within 10 to 12 years. Providing no further reserves are found at depth at Argyle, this would remove a yearly flow of several million carats of very small diamonds from the market. There are other large, undeveloped lamproite diamond deposits in Australia but their diamond concentrations appear to be too low for economic development (Appendix A). Any shortfall of near-gem diamond, perhaps even to the extent of the closure of Argyle, can be supplied primarily by the Zaire operations and, secondly, by all the other producers.

Large international mining companies are searching around the world for diamond mining region(s) that might succeed South Africa, Australia and, perhaps, Russia by the year 2000. The lead time required to develop a major pipe deposit pushes production from any new region back to the year 2000. The substantial stockpiling of uncut gem diamonds by the CSO suggests that to be successful, a new producer requires important reserves of gem rather than near-gem diamond. Exploration in Angola has identified kimberlite pipes in the northeastern area of the alluvial diamond fields. **De Beers** is negotiating the right to prospect for new kimberlite pipes in terms of an understanding reached with the Angolan government.[128] The diamond-bearing kimberlite pipes of the NWT are being evaluated for their economic potential with the financial backing of **BHP** and **RTZ**, two companies that mine and market a substantial share of the world's metals and non-metals. Development of a new major gem diamond mining region, be it in Canada, Africa or elsewhere, will likely face a production decision involving marketing negotiations with the CSO.

SUBSTANTIAL DOWNSIZING

Will the world's customers keep buying sufficient diamond rings and diamond jewellery during a long term recession? Will explorationists find more and more world-class deposits in the Precambrian Shields of Canada, Australia and South America, to name just a few of the less explored areas now receiving close scrutiny for diamonds? Can demand continue to keep pace with another increase in the long-term supply of natural gem diamond?

Marketing arrangements between the CSO and the present or future producers are crucial to the survival of the gem diamond industry. The CSO essentially controls the middle ground between the producers and the diamond cutting industry. An extended period of low demand coupled with continued oversupply may compel the CSO to exercise its contractual right to reduce diamond purchases from producers. Such action may not be welcomed by the independent Russians, the Australians or even, perhaps, the Batswana[129] who need their diamond mines running at capacity. Should the CSO be forced to substantially reduce its demand for rough diamonds from existing suppliers, the potential for a new diamond mining region in the NWT would lessen. However, based on the CSO's history of diamond marketing, this scenario appears unlikely.

NATURAL DIAMOND COMMODITY FAILURE

One way in which gem diamond could fail as a commodity would be if researchers of synthetic diamond manufacturing discover an inexpensive way to make commercial quantities of high quality, marketable diamond of any colour and stone size. Should this occur, the demand for expensive natural diamonds could plummet and diamond mines around the world may close.

Alternatively, as the marketing of gem diamonds is regulated by the fashion-conscious lifestyles of our society, a change in public opinion on the perceived importance of diamond jewellery would have a profound impact on the "diamond pipeline".

Neither the possibility of synthetic gem diamonds nor a fundamental change in diamond jewellery fashion trends appear likely at this time.

THE NWT DIAMOND RUSH

The NWT saw minor exploration for diamonds from the early 1970s to 1990 (Figure 5 and Table 3). A cluster of kimberlite pipes was discovered in the High Arctic on Somerset Island during the early 1970s.[130] These pipes were determined to be uneconomical for diamond from work performed by **Cominco Ltd** and **Diapros Ltd**. The Mackenzie River area was briefly explored for diamond by **De Beers** and several small companies during the late 1970s and early 1980s.[131] Several barren pipes were found in the mountains to the west of the Mackenzie River during the early 1980s.[132]

In 1991, junior company **Dia Met Minerals Ltd** and major mining company **BHP Minerals** announced the discovery of a diamond-bearing kimberlite pipe from a drilling program at Lac de Gras in the central mainland NWT.[133] This information provided the fuel for one of the largest land staking rushes in the world.

The information presented in this report on the NWT diamond play will be quickly outdated. The 45 millionth acre mark in the recording of claims in the NWT was surpassed in October, 1993. Events will continue to unfold rapidly because of the efforts being put into the NWT diamond rush by more than 150 companies.

LAC DE GRAS, NWT

The search for diamonds in the Lac de Gras area actually started far to the west in the Mackenzie River valley. A suite of diamond indicator minerals was originally found in the streams of the Blackwater Lake area, north of Wrigley during the early 1980s by both **Diapros Ltd** (then **De Beers**' Canadian exploration arm) and an independent group of geologists. One of the independents, Charles Fipke, continued sampling with encouraging results. The indicator mineral "trail" left by the glaciers led him away from the younger rocks of the western NWT and onto the Precambrian Shield. By the late 1980s, Fipke, now the president of **Dia Met**, was 700 km east of his starting point.

Fipke discovered the Point Lake kimberlite pipe at Lac de Gras in 1990, within kilometres of the winter road to the Lupin gold mine. Drilling in 1991 indicated that the pipe contained a concentration of diamonds in the economic range. A small, 160 tonne bulk sampling program performed during 1992 recovered 101 carats at 25% gem grade,[134] giving a preliminary diamond concentration of 0.63 carats per tonne. An early independent estimate suggested 73 million tonnes and 46 million carats to a depth of 220 metres for the 30 hectare Point Lake pipe.[135,136] The initial pipe was considered to be a potentially viable, moderately-sized deposit until a September 21, 1993 news release stated that further sampling yielded results that **"are too low to justify further exploration"**.[137]

By fall, 1993, more than 62 kimberlite pipes[138] had been found in the Lac de Gras area of the NWT (Table 3). **Dia Met** and **BHP** have located 26 pipes on their ground. A second consortium of companies lead by juniors **Southernera Resources Ltd** and **Aber Resources Ltd** and major **Kennecott Canada (RTZ** - parent company), announced that they had found eight pipes southeast of the Point Lake pipe during 1992. To the northwest, junior **Lytton Minerals Ltd** drilled the diamond-bearing Ranch Lake pipe during 1992 and junior **Tanqueray Resources Ltd** drilled the diamond-bearing Torrie pipe in 1993. Drilling information released in spring, 1993 by juniors **Dentonia Resources Ltd**, **Horseshoe Gold Mining Inc**, and **Kettle River Resources Ltd**, now collectively called **DHK Resources Ltd** and **Kennecott Canada** indicated that a target to the south of the **BHP-Dia Met** claim block contained diamonds in quantities comparable to the initial Point Lake pipe. Their Tli Kwi Cho double pipe has returned the best results for the pipes found to date on the **DHK** ground. Additional kimberlite pipes have been reported to the northwest and southeast of the **BHP- Dia Met** claim block. **Monopros Ltd** (an exploration arm of **De Beers**) holds a substantial land position in the Lac de Gras area but has not reported any results.

During the spring of 1993, **BHP** and **Dia Met** small-scale bulk sampled four selected pipes. Pipe surface areas have been indicated (but not yet confirmed) to be about 30 hectares. Gem content varies from 6 to 33% while diamond concentrations vary from 0.34 to 1.25 carats per tonne. The sampling of 'Pipe #4' recovered 62.11 carats of diamonds, appraised at an average value of US$112 per carat, from 49.8 tonnes of kimberlite. **Dia Met** announced plans to bulk sample a minimum of 3500 tonnes each from 'Pipes #3' and '#4', with bulk sampling to commence in early 1994.[139] **DHK** and **Kennecott Canada** announced a bulk sampling program to test the Tli Kwi Cho double pipe commencing during the winter of 1993/94.[140] Valuations of the gem diamonds recovered by their drilling programs have yet to be released by **DHK** and **Kennecott Canada**.

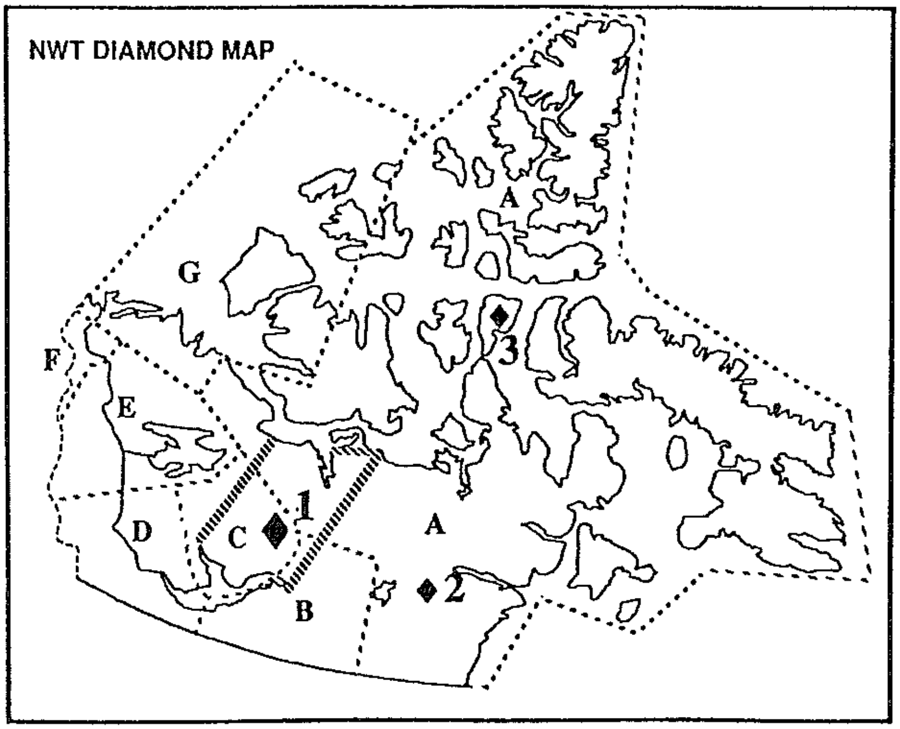
It must be emphasized that the news releases of the significant diamond discoveries near Lac de Gras signal the crossing of several initial hurdles on the road to a new mining region. The intent of the mining companies with potentially economic deposits is to generate the information required for a production decision. The next hurdle is the successful completion of bulk sampling programs, which for **BHP** and **Kennecott Canada** will consist of the small-scale mining of at least three pipes. If the diamond package evaluations are positive, then a production decision may require marketing negotiations between the owners of the deposit(s) and the CSO. Further, a potential mine requires environmental review and development permitting by the Governments of Canada and the Northwest Territories or review and permitting under the framework of a land claims agreement. Several more years of successful deposit evaluations and decisive negotiations will be required before the newspaper headlines say -

"NWT diamond mine to open!"

Major Mining Companies* Involved With Lac De Gras			
Company	Total Worth ($US Billions)	Sales ($US Billions)	Employees
BHP	18	11	49,000 (Worldwide)
RTZ	9	7	68,000 (Worldwide)
De Beers	7.3	3.4	18,790 (Mining Div)

* Figures from (1992) Annual Reports published by each company

The preliminary drilling and sampling results from several pipes invite favourable comparison of the Lac de Gras kimberlite pipe cluster to the diamond mining regions elsewhere in the world. The proving up of a major diamond mining region in the NWT continues unabated.



DIAMONDS AND THE NWT FIGURE 5 EMPR-GNWT (1993)

Slave Province of Canadian Precambrian Shield \\\\\\\\\\\\\\\\

Diamond Exploration Plays (Kimberlite Pipe Clusters) ◆

1. Lac de Gras
2. Dubawnt Lake
3. Somerset Island

Approximate Boundaries of Land Claim Areas - - - - - - - - - - -

A. Tungavik Federation of Nunavut (TFN) Settlement Area
B. South Slave Claim
C. North Slave Claim
D. Deh Cho Claim
E. Sahtu Claim
F. Gwich'in Settlement Area
G. Inuvialuit Settlement Area

TABLE 3

NWT DIAMOND SAMPLING RESULTS

KIMBERLITE	SAMPLE TYPE	SAMPLE WEIGHT(KG)	NUMBER OF DIAMONDS MACRO[1]	MICRO	100 KG EQUIVALENT #MACRO	#MICRO
LAC DE GRAS (1991-1993)						
BHP (POINT LAKE)	CORE	59.0	16	65	27	110
BHP-92-A	SURFACE	40.0	2	10	5	25
BHP-92-B	SURFACE	72.2	23	117	32	162
BHP-92-C	CORE	161.4	10	28	6	17
BHP-92-D	SOIL	25.7	2	2	8	8
BHP-92-E	CORE	69.9	11	36	16	52
BHP-92-F	CORE	199.9	65	212	33	106
BHP-92-G	CORE	122.0	8	45	7	37
BHP-92-H	CORE	60.0	1	7	2	12
BHP-92-I	CORE	122.4	55	132	45	108
BHP-93-A	CORE	85.5	19	60	22	70
BHP-93-J	CORE	60.5	155	259	255	428
ABER-92-1A	CORE	7.9	--	2	--	25
ABER-92-1B	CORE	8	--	1	--	13
ABER-92-5	CORE	5-8	--	2	--	25-40
ABER-92-7	CORE	5-8	--	1	--	13-20
DHK (TLI KWI CHO)	CORE	313.7	96	299	29	95
DHK (NORTH LOBE)	CORE	265.2	16	62	6	23
DHK-93 (DD-17)	CORE	182.1	14	37	7	20
DHK-93 (DD-42)	CORE	146.4	9	31	6	21
DHK-93 (DO-32)	CORE	86.6	--	1	--	1
DHK-93 (DD- 39)	CORE	216.8	7	32	3	15
DHK-93 (DO-40)	CORE	3.8	--	--	--	--
DHK-93 (DO-41)	CORE	122.1	--	1	--	1
LYTTON (RANCH LAKE)	CORE	208.1	6	38	3	18
TANQUERAY (TORRIE)	CORE	162	39	152	24	94
DUBAWNT LAKE (1992)						
92-D280	SURFACE	71.4	--	1	--	1
SOMERSET ISLAND (1973-1974)						
NORD	SURFACE	12635	1	--	--	--
BATTY	SURFACE	144910	2	--	--	--
SELATIAVAK	SURFACE	25-45	--	5	--	11-20
PEUYUK	SURFACE	1375	--	3	--	--
CORDILLERAN REGION (1981)						
MOUNTAIN	SURFACE	100	--	6	--	6

Modified from J. Pell (1993); News Releases: 5 Nov/91 and 8 Dec/92 by Dia Met Minerals; 6 May, 3 Aug and 5 Sept/93 by DHK Resources

SMALL-SCALE BULK SAMPLING RESULTS OF LAC DE GRAS PIPES

KIMBERLITE	ROTARY DRILLING[2] SAMPLE (TONNES)	CARATS[2]	APPROXIMATE % OF GEMS[2]	PRELIMINARY CARATS/TONNE	VALUE[2] US$/CT
BHP - POINT LAKE	160	101	25%	0.63	Uneconomic
BHP - PIPE #1	151.2	65.37	17	0.43	$89
BHP - PIPE #2	21.2	17.99	6	0.84	Uneconomic
BHP - PIPE #3	179.7	61.28	33	0.34	$81
BHP - PIPE #4	49.8	62.11	31	1.25	$112

[1] Macrodiamond is >0.5 mm [2] 21 June/93 and 21 Sept/93 News Releases by Dia Met Minerals Ltd

ELSEWHERE IN THE NWT

Many exploration mining companies are trying to find the next diamond-bearing kimberlite pipe cluster in the NWT. The oldest parts of the Precambrian Shield in the NWT have been staked by diamond explorers including, in particular, the part that geologists call the Slave Province. This area extends from the north shore of Great Slave Lake northward to Bathurst Inlet and the Tree River on the Arctic coast. Staking is still proceeding westward towards Great Bear Lake and eastward beyond the Thelon Game Sanctuary. Additional staking has spilled over into the Keewatin, particularly south of Baker Lake and west to the Thelon Game Sanctuary. This area, like the Slave Province, is underlain by old rocks of the Canadian Shield.

Micas from one of the kimberlite pipes at Lac de Gras are 52 million years old.[142] One implication of such a young age is that potential diamond-bearing kimberlites are not restricted by timing emplacement constraints to the exposed Precambrian Shield. The sedimentary rock packages overlaying the Precambrian Shield north to the High Arctic islands, west to the Mackenzie Mountains and south to the Prairie Provinces are also highly prospective. Areas of recent interest in the NWT include the Lac la Martre area, the Horn Plateau and the Fort Smith area. In the Keewatin, a diamond has been found in an occurrence thought to be a kimberlite pipe at Dubawnt Lake.[143] Ten kimberlite occurrences have been identified from 21 targets in the Keewatin by **Leeward Capital Corp.**[144] Gravel beaches along and inland from the Arctic coast have been staked for evaluation of their diamond placer potential.[145] In the high Arctic, the kimberlite pipes on Somerset Island are being re-examined.[146]

ELSEWHERE IN CANADA

Major portions of Alberta and Saskatchewan have been staked for diamonds. Other areas of interest include northern Manitoba, northern Ontario and northern Quebec.

Diamond-bearing kimberlite pipes were discovered in the Kirkland Lake area of northern Ontario in the early 1960s,[147] and in the Prince Albert area of northern Saskatchewan in the late 1980s.[148] The work to date has shown the Ontario kimberlite pipes to be uneconomic with diamond grades and concentrations similar to the kimberlite pipe cluster on Somerset Island, NWT. The Saskatchewan deposits, although large, are subeconomic with the best result (1992) of 0.1 carats per tonne. Recently, 138 macrodiamonds with a total weight of 7.61 carats from 131.7 tonnes were collected by bulk sampling a trio of kimberlite pipes near Fort à la Corne, 80 km east of Prince Albert, Saskatchewan.[149,150] Unlike the Lac de Gras, NWT pipe cluster, the Fort a la Corne pipe cluster is buried beneath 100 metres of soil and overburden. A further 50 targets in this particular Saskatchewan diamond play require testing.

CHALLENGES FACING POTENTIAL DIAMOND DEVELOPMENT

State of the art of diamond exploration in Canada is presently directed towards a cluster of kimberlite pipes of economic potential discovered at Lac de Gras in the central Slave Province of the NWT. Preliminary news releases indicate that several of the discoveries are of comparable diamond concentration, deposit size and gem diamond valuation relative to mines in southern Africa and Russia. **BHP Minerals** and **Dia Met Minerals Ltd** have announced plans to proceed with the bulk sampling of 3,500 or more tonnes each from two pipes; while **Kennecott Canada** and the **DHK** consortium have announced a 5,000 tonne bulk sampling program for their double pipe. However, several years of deposit evaluations and subsequent marketing negotiations lie ahead before an announcement of diamond mining in the NWT may be made. It should be noted that in the past, newly substantiated diamond mining regions saw production relatively quickly.

Based on the history of diamond mining in southern Africa and Russia, hundreds of kimberlite pipes remain to be discovered in the Canadian Shield. The great majority of pipes will not be economic but the incentive of finding multi-billion dollar deposits will provide for much exploration activity in the North for years to come. Millions of hectares of land in the central Northwest Territories are receiving close scrutiny from the mineral exploration industry. New discoveries of deposits other than gem diamonds, particularly gold and base metals, are a reasonable expectation.

Should exploration be successful in outlining economic concentrations of gem diamonds at Lac de Gras, the opportunity of diamond mining would present itself to the residents of the NWT. Northern residents will judge any new mining development on the basis of protection of the environment and benefits to the NWT. Some technical, environmental and health-related matters concerning diamond mining were found during the course of the review of available literature. These factors, as well as the challenges of climate, permafrost, remoteness and the lack of infrastructure, will need to be addressed in order for diamond mining in the NWT to become a reality.

ENVIRONMENTAL PROTECTION

Environmental considerations are important factors in the planning, construction, productive life and rehabilitation of any mine. Complying with environmental and conservation legislation is a vital element in current mine planning.

The current system of environmental review and approvals will handle the permitting of a new diamond mine. The physical properties of kimberlite, a comparatively soft, weak rock, may require assessment for mine safety reasons. The mining and processing of kimberlite may require further review of dust suppression measures if the mineral serpentine is present. A diamond mine processes kimberlite mechanically, not chemically. Due to the weak to moderate alkaline nature of kimberlite, the tailings would not be acid-forming nor contribute sulphide metals to mine drainage. Depending on the degree of alkalinity, kimberlite tailings may be chemically inert and not represent an environmental threat. However, the environmental reviews performed for the mining of diamond-bearing kimberlite pipes elsewhere in the world may not be to North American standards and further studies may be warranted.

INFRASTRUCTURE

Every large diamond mine in the world has road access and most have an airfield. Based on the present infrastructure in the North, a diamond mine in the NWT would be a fly-in/fly-out operation. In Yakutia, the Russians constructed a 750 km all-weather road linking all the diamond mines, new townsites and existing population centres to the port of Lensk on the River Lena.[151] There are an additional 2000 km of winter roads in the Siberian diamond mining region which were used initially to develop the Yakutian mines and townsites.

The present NWT winter road system provides cold weather access to the communities of the Mackenzie River Valley and to the Lupin gold mine of **Echo Bay Mines Ltd** near the Arctic Circle. The potential development of a diamond mining region in the central NWT would initially require access to the deposit(s) from the **Echo Bay** winter road. An all-weather road, in part supported by the presence of a major diamond mining region, may be feasible when combined with other potential resource developments such as the nearby Izok base metal deposit. Ultimately, an 800 km road to Coppermine could be built.[152] This road, in turn, would support other long term economic development. As diamond operations generally require three to four times the yearly supplies than that of a typical gold mine, the present winter road may not be able to support such a volume of traffic. It has been suggested that extending the all-weather road to Mackay Lake would allow potential diamond mines to be resupplied via barge and winter road across Mackay Lake. The preliminary cost for a 220 km permanent road from Tibbitt Lake to Mackay Lake would be close to $Cdn200 million. No single mining company or government could bear this cost.

Existing and potential power infrastructure in the NWT needs to be examined due to the presence of a potential diamond mine. A large diamond mine requires up to 20 megawatts[153] of hydro- or diesel-generated power. The mine's processing plant consumes the bulk of the power. A 20 to 40 megawatt hydro site could be developed and dedicated to a single, long term mine, with the amortization (or cost of the investment) written off over the mine's lifespan. The development of a mining region with several producers, whether mining diamonds, gold or base metals, would support the development of a larger hydro power infrastructure. However, dependent upon the demand requirements and the dam site construction details, it could take three to ten or more years to complete a hydroelectric project from concept to commission. The process of identifying and evaluating hydro sites in the NWT is currently underway.

EMPLOYMENT

Lack of education is the greatest impediment to increased northern employment in the resource industries. Many of the jobs at a modern mining operation are held by persons with minimum education levels of Grade 10-12, training and experience. The key enabling NWT residents to obtain employment at a potential diamond mine is a high school diploma or the equivalent, which can open the door to mine training programs. Mining companies are beginning to work with the Government of the Northwest Territories (GNWT) in order to develop mining and trade education packages at Arctic College aimed specifically at the needs of future mining projects.[154]

The GNWT supports benefit agreements between the mining industry and communities as a way of ensuring the participation of Northerners in new mining ventures. Factors such as transportation for workers, business opportunities, location of workers and general working conditions are addressed in the agreements. In this manner, the issue of northern hiring by a large fly-in/fly-out operation could be addressed. Clearly, the NWT would benefit the most if northern residents are employed.

HEALTH HAZARDS

Diamond mining uses basic principles applied by open pit mining in general. The mining of kimberlite has never been scrutinized by health and safety authorities who, in North America, are focused on quartz mining (silicosis), uranium mining (radon gas), coal mining (coal dust and methane) and asbestos mining (asbestosis). Fortunately, kimberlite has little to no quartz or radioactive minerals.[155]

Of concern as a potential health hazard is the very fine-grained mineral, serpentine, which can be present in kimberlite. Asbestos is a type of serpentine. "Few studies have attempted to identify the serpentine species present. (Researchers) have noted that it is not possible to identify unequivocally lizardite, chrysotile or any of their polytypes by conventional XRD (X-Ray Diffraction) techniques."[156] Russian research suggests that secondary (or weathered) serpentine is extremely fine-grained and exhibits fibre- or asbestos-like characteristics. Under the Russians' microscopes, the diameter of the **"particles of newly formed serpentine...reaches 0.5 µm (10^{-6} metres). Individual globules (of serpentine) congregate into extended snakelike growths."**[157]

Threshold Limit Values For Selected Substances[158]

Substance	Threshold Limit	Comments
Serpentine	----	not listed by ACGIH*
Mica	3 mg/m^3	respirable dust
Barium	0.5 mg/m^3	soluble compound, as Ba
Portland Cement	10 mg/m^3	(often used to grout tunnel walls)
Asbestos		
Amosite	0.5 fibre/cc	fibrous mineral
Chrysotile	2 fibres/cc	Canadian asbestos(type of serpentine)
Crocidolite	0.2 fibre/cc	fibrous mineral
Other forms	2 fibres/cc	
For Comparison Only		
Silica	0.1 mg/m^3	respirable quartz dust, (quartz is very rare in kimberlite)
Soapstone	3 mg/m^3	respirable dust

*ACGIH [American Conference of Governmental Industrial Hygienists)

Mica may also be present in kimberlite in the amounts of 1 - >50%.[159] Mica has the same respirable dust threshold limit of 3 mg/m^3 as soapstone.

Dust suppression measures may require review, as dust will be created from the mining, processing and tailings impoundment of kimberlite.

DEEP OPEN PIT MINING IN ARCTIC CLIMATE

Deep, open pit mines in Arctic regions exist only in Russia. Due to temperature inversions, carbon monoxide and other exhaust gases from operating machinery increase to unacceptable levels in the bottoms of their open pits. **"Total downtime due to gassiness (from high capacity vehicles' exhaust gases) at the 'Udachnaya' pipe open pit in 1990 amounted to 1529 hours."**[160]

Permafrost is a fact of life at any minesite in the Far North. Permafrost enhances ground stability at the underground operations of the Polaris and Lupin mines in the NWT. The Russians, who have experience with open pit mining in permafrost, have established the Russian Permafrost Institute, which could prove to be a valuable source of information on northern mining.

MINE SAFETY

Slope failure at an open pit diamond mine is not mentioned in the literature acquired to date. However, difficulties in ground control at South African underground diamond mining operations were noted. **"Serious deterioration of all workings in the mine and surrounding rock, between the 900-foot and the 1,950-foot levels"**[161] was induced by the block caving mining method employed during the early 1960s and by the nature of the country rock at the Jagersfontein mine. Production was suspended at the Wesselton mine in February, 1992 **"owing to two major mud pushes on the 850 metre level"**[162]. Photos show underground tunnelling in kimberlite to have the walls "grouted" or sealed with cement.[163]

> **"Underground (diamond) mining methods...involve working at considerable depth under a moving mass of caved material and over relatively large areas in comparatively weak rock."** 164

Because **"kimberlite deteriorates rapidly once exposed to air"**[165] the engineering designers of underground diamond mines try to put as much of the development as possible outside the ore. **"The final development within the ore body will only be undertaken near the time the underground project is scheduled for commissioning."**[166]

Russian diamond mines also have the problem of toxic salt brines in groundwater[167] and methane gas from petroleum fluids.[168] The Russian kimberlite pipes occur in porous, oil-rich sedimentary rocks that overlay the Siberian Precambrian Shield. Salt brines and petroleum fluids are not anticipated from the present diamond exploration in the NWT where the kimberlite pipes are restricted to the hard, dense rocks of the Precambrian Shield.

Pockets of high-pressure gas have been encountered by the Russians in the drilling and mining of kimberlite. It is not clear from the literature if they believe that their gas problem may be due, in part, to gases left unvented from the very gas-rich mechanism of kimberlite pipe emplacement, or due completely to the presence of petroleum fluids in the sedimentary country rocks.

> **"Free (methane-rich) gases are extremely widespread in the Udachnaya pipe. They were found in many pits excavated in fracture zones, as well as in drillholes at depths ranging from 10 to 1000m. The quantity of gas liberated spontaneously was variable and locally reached hundreds of thousands of cubic metres. For example, there was a blowout of fuel gas from a depth of 367.5 m in drillhole No. 42 in the east ore body; its yield was about 100,000 m^3, and the initial pressure ranged from 50 to 70 atm."** 169

However, specific reference to gas pockets at the kimberlite pipe mines in South Africa and Botswana is not mentioned in the literature acquired to date.

MINE DISCHARGES, TAILINGS AND WASTE ROCK DUMPS

> **"Udachninsky mining and concentration combine (Udachnaya diamond mine) after suppression and purification makes an average annual emission into the atmosphere of 700 t (tonnes) of dust, 3500 t of carbon monoxide, 1500 t of nitrogen dioxide, discharges into surface water reservoirs 5500 thousand m^3 of domestic wastewater, (and) up to 3000 thousand m^3 of industrial wastewater."** [170]

The Russians have quantified the emissions and discharges from a large diamond open pit mining operation, the values of which may or may not be typical for a large North American mining venture actively applying environmental safeguards. Further research is required.

The major volume of waste material produced by any large open-pit mining operation is waste rock plus tailings from processing. Waste rock at a potential NWT diamond mine would consist of Precambrian Shield rocks which, depending on its acid rock drainage (ARD) characteristics, would probably require no special handling. Kimberlite has a very low content of sulphur and base metal sulphides.[171] The tailings consist of kimberlite crushed to fine sand-sized particles with an infinitesimal amount of diamonds removed. No leaching chemicals are used in the milling circuit. Therefore, tailings are not acid-forming nor do they contribute significant toxic metals to groundwater and runoff. However, a study of the weathered, clay-rich caps of kimberlite pipes in Russia indicates that weak to moderate alkaline conditions prevail.[172]

SECURITY

The theft of a single, large stone could significantly affect a diamond mine's earnings. Diamond mining requires security to the extent experienced at very high-grade gold mines or, perhaps, the Canadian Mint gold refinery in Winnipeg.

The only published details about diamond security measures are from the Orapa diamond mine in Botswana,[173] which has a 3.2 km-wide "no-man's land" perimeter. At the mine itself are a series of fenced and gate-controlled areas. The entire minesite is fenced. Access to the mill is controlled. The heavy media separation and diamond recovery area of the plant has additional security measures. However, security measures at an isolated minesite in the NWT would be focused on the diamond recovery area, controlling access to the minesite and guarding diamond shipments transported from the mine to the market.

Diamond mines have armed guards plus strip and X-ray searches of personnel.[174] Diamond is not touched by human hands during recovery at the processing plant. "Glove boxes"[175], used to sort the diamonds recovered at the minesite, are rubber gloves and arm gauntlets set in a plate of glass that separate the human sorter from the rough diamond.

The security measures required by diamond mining may result in changes in the legislation which governs regular law enforcement agencies.[176]

TAXATION

Diamond mines generate significant revenues to governments worldwide. In the NWT, a share of potential royalties will also be collected by land claimants. However, both the federal mineral royalty system and the territorial corporate tax system are profit based; the greater the amount of money made over expenses, the more tax and royalty levied. There are over 5000 grades for diamonds and the value of each grade varies. The diamonds produced by a mine are sorted and valued by the individual stone against a "Master Sample" applicable to all the producers in the world. The valuation is approved by an independent valuator appointed by the mining company and/or the government before the transaction is completed between the producer and the CSO.[177] From a government administrative point of view, this is a significant change to the system currently in place in the NWT. The current royalty and taxation systems may need to be reconsidered in order to ensure a continuing high level of investment in diamond exploration and mining plus a reasonable return to the government.

NWT DIAMOND CUTTING INDUSTRY

A diamond cutting facility could employ a substantial number of Northerners. However, the development of a cutting industry in the NWT may be difficult. International trade agreements limit the options of the territorial and federal governments in controlling or holding back some of the export of uncut diamond stones. Competition from skilled low-wage cutters in Asian countries have recently caused the closure of a number of government-backed cutting facilities in several diamond-producing countries. The benefits of potential Northern involvement in the diamond cutting industry would have to be carefully weighed against the disadvantages.

DIAMOND MARKETING

If a diamond mining industry were to be established in the NWT, industry and government would have to deal with the option of using the CSO's marketing facilities. It would appear that maintaining a stable market is paramount for gem diamonds to proceed from the mines, via the traders, cutters and retailers, to the recipients of diamond rings and jewellery.

CONCLUSIONS

During the past three years, significant diamond discoveries in the NWT have precipitated a huge land staking rush and sparked the interest of several large multinational mining companies and many Canadian exploration companies. Preliminary results from sampling programs suggest that the NWT could become the world's next important producer of gem diamonds. Several deposits of economic potential are being evaluated for their concentrations, qualities and quantities of diamonds. Many people in the mining and exploration industry are optimistic that a "diamond boom" lies ahead for the NWT.

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