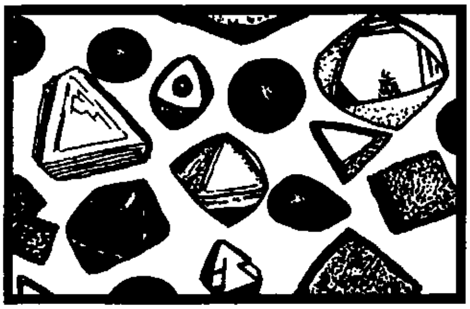

Geological Knowledge: A Key to the Future of the Diamond Industry

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SUMMARY
The geological knowledge needed to find diamond deposits has increased substantially since the early 1950s and is now readily available in the public domain. This has resulted in the discovery of many new diamond deposits in the last 50 years and, therefore, an oversupply of rough diamonds at various times. Based on analogies with other mineral commodities, new diamond deposits will be found at an accelerated rate as diamond-related geological knowledge continues to expand and exploration methods are refined. In such circumstances, as with all commodities, in the long term (>20 years) new markets must be found to keep pace with increased production, otherwise there may be an ever-present concern based on oversupply.

RÉSUMÉ
La somme des connaissances géologiques requises en vue de découvrir des gisements de diamants s'est considérablement accrue depuis le début des années 50 et, ces connaissances ayant été largement diffusées depuis, chacun peut maintenant y accéder. En conséquence, depuis les derniers 50 ans, un grand nombre de gisements de diamants ont été découverts, à tel point que par moments, il y a eu surplus de l'offre de diamants bruts. Comme pour tout autre matière première minérale le nombre de nouvelles découvertes diamantifères ira s'accélérant au fur et à mesure de l'acquisition de nouvelles connaissances géologiques et du raffinement des méthodes d'exploration. Et, comme pour toute matière première, il faudra à terme (20 ans et plus) découvrir de nouveaux marchés sans quoi, l'industrie sera constamment au prise avec un problème de surplus.

INTRODUCTION
During the last decade of the 20th century the diamond industry experienced a series of seemingly unrelated events that caused concern in various quarters of the diamond trade. Some of these events lasted for short periods of time, ranging from months to years and have since been remedied, whereas others are longer term (*e.g.*, Sevdermish *et al.*, 1998a,b). For example, diamond producers were concerned about "dumping" from Russian stocks, unbridled mining in civil-war-ravaged Angola, the marketing of Argyle (Australia) production outside the Central Selling Organisation (CSO) of De Beers, and the oncoming production from new major pipe mines in Canada, Russia and Angola. The manufacturing (cutting and polishing) sector was concerned by the limited amount of rough released by the CSO, extremely small profit margins, and the long-term effect of India as an increasingly important cutting centre. Both the wholesale and retail sectors were concerned about the decline in the economies of Japan and southeast Asia, an oversupply of small polished stones cut in India, and the effect of mass marketers and Internet dealers taking market share from traditional jewelers.

We believe that all of the above concerns are interrelated and have occurred because De Beers no longer controls a sufficiently large percentage of the world's rough diamond mine production and marketing (through the CSO) to maintain the stability so characteristic of the diamond industry in the past. At present, mines owned by De Beers (including its governmental partners in Botswana and Namibia) account for about 28% of the world's diamond production by weight and 50% by value (Picton *et al.*, 1999), whereas in the past these values were significantly higher. The fundamental reason for this situation can be attributed to one fact: the geological knowledge needed to find diamond deposits is now readily available and, as a result, there are several new diamond-producing companies in several countries anxious to sell their production. But, were there not problems of similar magnitude in the earlier decades of this century? And, if so, how were they resolved?

SOME HISTORICAL REALITIES
At various times in the 20th century the diamond industry did, indeed, face severe challenges, but they were always overcome by the timely and effective actions taken by De Beers and/or the CSO. These actions were successful because De Beers was the only significant gem diamond producer and explorer in the world until the 1950s and, therefore, could control the amount and price of diamonds entering the pipeline, *i.e.*, being released to the cutting centres through the CSO (Sevdermish *et al.*, 1998b). Thus, during the Great Depression when diamond production and retail markets were small by the standards of today, essentially all of De Beers' diamond mines in South Africa and Namibia were closed, effectively eliminating new gem production. And, during the period of inflation and diamond speculation in the late 1970s and early 1980s when the industry was buffeted by extreme price volatility, the CSO introduced surcharges on rough diamonds to stabilize the industry. The ability of De Beers to deal with major new gem diamond production from 1960 (starting with Russia) until the early part of this decade merits acclaim. From 1960-1990 De Beers was able to maintain stability throughout the entire diamond pipeline, in spite of the emergence of new producing entities, by means of contracts covering the production and/or marketing of their rough diamonds.

Figure 1 graphically shows the increase in total annual production of rough diamonds from 1900 to 2000 (projected to be 120 million carats; Mct). From 1900 to 1960 total annual world production increased from 2.1 Mct to 27.7 Mct (Levinson *et al.*, 1992) of which at least 95% came from countries in Africa (Janse, 1996). Most of this production was either controlled by, or marketed through, De Beers/CSO. From

1960-1990 worldwide production of newly mined rough diamonds increased almost four-fold (from 27.7 to 101 Mct). However, most of this more recent increase occurred from major new discoveries in countries that previously never had produced diamonds (or only in insignificant amounts), namely Russia, Botswana and Australia (Argyle mine). Both Russia and Australia had the technical and financial capabilities to mine and market rough diamonds independently and, thus, they had the potential to create the first serious challenge to the single-channel marketing system of De Beers. Yet this did not occur because De Beers/CSO was able to enter into the eminently successful, mutually advantageous, marketing contracts for rough diamonds mentioned above.

Starting in 1990 conditions began to change. The Soviet Union was transformed into independent states, and for much of the 1990s it was not in the interests of Russia to market as much of its production through the CSO as it had done previously. Similarly, since 1996 diamonds from the Argyle mine have been marketed independently from the CSO. From this time (early 1990s) onward De Beers' domination of the sources of gem diamond production, either by ownership or contract, has not been as absolute as it was in the past (Sevdermish *et al.*, 1998b). Significant amounts of diamonds were marketed outside the single channel marketing system of De Beers/CSO. This situation occurred because since the mid-1950s geologists, in Russia and elsewhere, were able to make major new discoveries of both primary (pipes) and secondary (*e.g.*, alluvial, marine) diamond deposits.

EVOLUTION OF GEOLOGICAL EXPLORATION TECHNIQUES FOR DIAMONDS

In the period before World War II rough diamond production and exploration were mainly confined to Africa, including alluvial deposits of Zaire, Angola and West Africa. Economic kimberlite pipes were known only in South Africa. Exploration techniques included the use of indicator minerals (*e.g.*, garnet), known since the 1870s (Janse, 1996; Atkinson, 1989), and geophysics (*e.g.*, ground magnetic surveys to locate the boundaries of kimberlite pipes), which was first used successfully in South Africa in 1932 (Krahmann, 1988). These techniques were primitive by today's standards, however, and were limited to a small number of relatively accessible areas. In addition to the limited knowledge base, much of what was known was proprietary to De Beers. Noteworthy is the fact that although indicator minerals were known in South Africa since the 1870s, and that they had assisted in the discovery of the Premier mine in 1903 (Atkinson, 1989), they were not prominent in the exploration methods used by De Beers in the first half of the 20th century. Rather, De Beers' exploration was based primarily on the "diamond trail" technique, *i.e.*, systematically collecting large samples (~1 tonne) of river gravels from which diamonds were recovered. Starting in 1955, however, following the discovery of kimberlites in Russia by means of the "pyrope garnet trail," emphasis shifted to the use of garnets and other indicator minerals (A.J.A. Janse, personal communication, January 2000). Similarly, geophysics was not used to its fullest capabilities by De Beers in this time period.

Since World War II there has been a great increase in expenditures for diamond exploration research, resulting in an increase in applicable geological knowledge (Atkinson, 1989). Major exploration advances for primary diamonds deposits include: (a) improved area selection techniques on Archean cratons based on geophysics, geochemistry, and geochronology; (b) understanding the scientific basis for interpreting the chemistry of indicator minerals (*e.g.*, "G10" garnet, high magnesium ilmenite) abetted by the introduction of the electron microprobe in the 1960s; (c) recognition that economic diamond deposits may occur in rock types other than kimberlite (*i.e.*, lamproite); (d) microdiamond/macrodiamond ratios on small samples to estimate economic potential of kimberlite pipes (grade prediction) (*e.g.*, Deakin and Boxer, 1989); and (e) highly improved airborne geophysical techniques (*e.g.*, aeromagnetic and airborne electrical surveys since the 1970s; Cook, 1997). For secondary diamond deposits a variety of geophysical techniques (*e.g.*, seismic reflection profiling, ground penetrating radar) are used depending on the nature of the deposit being sought, *e.g.*, marine, beach, alluvial (Cook, 1997).

All of these techniques are con-

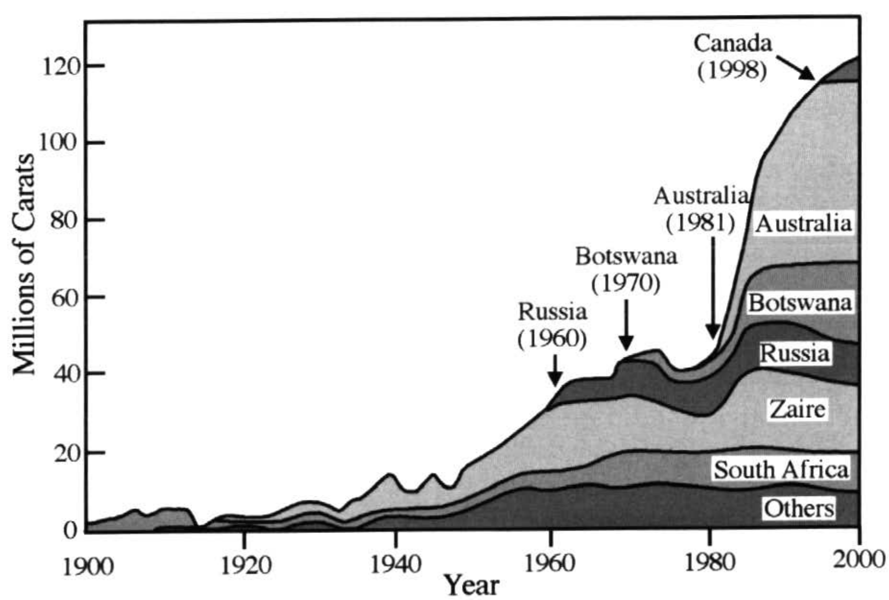

Figure 1 Graph showing the 60-fold increase in total annual world production of rough diamonds (both gem and industrial) from 1900-2000 (projected), from about 2 to 120 million carats. In this same period the world's population increased 4-fold, from about 1.5 to 6.0 billion. The arrows indicate the approximate years in which major sources noted in the text (Russia, Botswana, Australia, Canada) began significant production (after Atkinson, 1989, and based primarily on data from Levinson *et al.*, 1992; United States Geological Survey, 1999; and Picton *et al.*, 1999).

tinually being improved and/or their resolution is being increased, and interpretations are being refined (sometimes at the expense of costly mistakes!). Since the 1950s, this improved and newly acquired geological knowledge has been applied particularly to previously remote and inhospitable, but geologically favorable, areas (e.g., the Archean cratons of Siberia, northern Australia, northern Canada).

EXAMPLES OF THE RESULTS OF INCREASED GEOLOGICAL KNOWLEDGE

One product of geological knowledge is exploration success. Only two kimberlite pipes that produced more than 3 Mct annually were found in the first 50 years of the 20th century; both are in southern Africa (Premier in South Africa and Mbuji-Mayi in Zaire). In the past 50 years eight major kimberlite (or lamproite) discoveries were made, each of which produce at least that amount annually: Argyle (Australia), Orapa and Jwaneng (Botswana), Finsch and Venetia (South Africa), Mir and Udachnaya (Russia), and the multiple pipes at Ekati™ (Canada). Based on the current state of exploration and development, perhaps another six large kimberlite mines will be producing within the next 10 years, most likely in Canada (*e.g.*, Diavik), Russia and Angola. (In the same time frame, several mines will likely close, *e.g.*, Argyle, the remaining mines in the Kimberley cluster in South Africa, and some older Russian mines.) In 1950 diamonds were mined in 13 countries; today 23 countries have economic primary (pipe) and/or secondary (*e.g.*, alluvial) mines (*e.g.*, Levinson *et al.*, 1992, Janse, 1996; Picton *et al.*, 1999).

Increased geological knowledge has resulted in new discoveries and increased production for many mineral commodities, *e.g.*, uranium, copper, gold, oil and natural gas, and nickel (in some cases improved beneficiation technology played a part, *e.g.*, heap leaching of gold). Concomitant with the production increases of these commodities there generally have been increases in the number of: producing countries, companies mining the commodity, and geological types of deposits in which the commodity occurs. This scenario is well illustrated with nickel. In 1940, Canada produced (from sulfide deposits) at least 75% of the world's nickel with most of the remainder coming from New Caledonia (from laterites) and Russia (from sulfides). Today, due to vast improvements in geological knowledge of nickel deposits, as well as improved and new extraction methods, additional major nickel producing countries with annual production of more than 20,000 metric tons of nickel include Australia, Botswana, Brazil, China, Colombia, Cuba, Dominican Republic, Indonesia, and South Africa (Russia is now the world's largest producer). Australia alone has nine producing nickel mines (three based on laterite) and 10 projects pending ("Western Australia: nickel in a nutshell," 1999).

DISCUSSION

Global diamond exploration has grown dramatically in recent years and is at an all time high. The number of listed companies exploring predominantly for diamonds was 23 prior to 1992, 45 in 1992-1994, and 74 in 1995-1998 (Robinson, 1998). In 1998 the world diamond exploration budget was about US$300 million. The incentives are (Robinson, 1998): Canadian successes; increased accessibility to prospective land areas; ready availability of risk capital; and, possibly most importantly, relative stability of the diamond market compared to other mineral resource commodities. In view of the above it is not surprising that diamond exploration has attracted the attention of several large mining companies (*e.g.*, BHP, Rio Tinto) with great technical and financial resources. Without doubt, some of the new explorers, like BHP presently, eventually will become new producers, thus increasing the potential diversity of rough diamond producers.

In Canada, more than 300 kimberlites have been discovered in the Slave Geological Province alone (Picton *et al.*, 1999) since 1991. De Beers, who has been exploring in Canada at least since the 1960s, has discovered more than 170 kimberlites (some with joint venture partners) in 11 different (unspecified) regions (Beardmore-Gray, 1999). By 2003 it is likely there will be at least two diamond mines in Canada — Ekati™ and Diavik — whose combined annual production will account for about 10% of the world's diamonds by value and 8% by weight. Further, there may be several additional but smaller diamond mines in Canada by 2010. Ownership of the production from the several mines will be in the hands of perhaps a dozen different companies and individuals, as virtually every potential mine is owned by various joint venture partners whose contracts may allow each to sell its share of the production independently.

Established diamond producing countries also have been active and successful in developing new deposits or expanding the capacity of present mines. For example, exploration in Russia continues unabated. In Yakutia (Siberia) the annual exploration budget is US$27-30 million ("Russian gem diamond production...," 1999). Since the discovery of diamonds in this region in the 1950s, more than 800 kimberlites have been discovered, 150 of which are reportedly diamondiferous, but so far only 13 have proved economic (Hill, 1997). By 2005, annual Russian production is expected to increase by about 35% over that in 1999, to about US$2.2 billion in value ("Russian gem diamond production...," 1999); assuming an average value of US$100 per carat for the Russian rough diamonds, this implies production of about 22 Mct in 2005. Further into the future, some (possibly optimistic) estimates suggest that Russian rough diamond production will eventually reach 2.5 times that of 1999 (*e.g.*, Picton *et al.*, 1999). At that time, it is estimated that Yakutia, the present source of 98% of Russia's production, will account for only about 40% of the future expanded production. The remaining 60% will come primarily from areas presently being explored and evaluated but which currently have no production: Northern European Russia (*e.g.*, the Arkangelsk region) and southern Siberia ("Russian gem diamond production...," 1999; Picton *et al.*, 1999).

It is uncertain whether the long-term growth of the diamond jewelry market can increase in proportion to the supply. Based on experiences with many other mineral commodities, *e.g.*, gold, when exploration successes are achieved, the appetite of the exploration sector becomes insatiable, and discoveries accelerate. In such a scenario, there may well be a chronic oversupply. Such a possibility was recognized by Mr. George Burne, a De Beers executive, who posed a question seldom at the top of the exploration agenda: "Will we find too many diamonds – and what will happen if we do?" ("Canada set to become...," 1999, p. 8).

We would like to emphasize that the premise on which this paper is based is not concerned with short term volatility and perturbations in the supply and demand cycles of the diamond world because of economic, political, environmental or other reasons. Further, it is not our intention to make specific predictions for the next 5-10 years. Thus, for example, in the long term (which, for the sake of discussion, we define as more than 20 years) the present civil strife in Angola that is disrupting diamond exploration and production, the possibility that new mines in Canada will be delayed for environmental reasons, or that financing may not now be obtainable for new mines in Russia, are of only minor significance in the overall picture because they are short term phenomena; they may even cause a temporary decrease in the supply in rough diamonds. No matter what happens in any, or even all, of these presently problematic areas, it will not affect our major premise, which is that geological knowledge of how to find diamonds will continue to grow, exploration will become more efficient and effective, and more economic diamond deposits will be found.

CONCLUSIONS

Before 1955 De Beers owned most of the world's important gem diamond deposits as well as much of the geological knowledge available at the time to find them; the combination resulted in stability throughout the entire industry. Since then, starting with the Russian discoveries in the mid-1950s based primarily on the use of indicator minerals, there have been remarkable advances in our understanding of, and the theoretical basis for, improved and new exploration techniques. Much of this information is now in the public domain. This explains the discovery, since the mid-1950s, by nations and companies other than De Beers, of a large number of important diamond deposits, specifically, those in Russia, Australia and Canada. Thus, lack of expertise is no longer a barrier to diamond exploration that, with time, is likely to become ever more sophisticated, reliable, and successful. The application of this technology cannot be suppressed or reversed, which implies that inevitably there will be an increased diversity of supply of rough diamonds in the 21st century.

Many of the deposits found in the future may be owned by companies or governments that have no historical relationship to De Beers or commitment to market their diamonds through the CSO. Inherent in this scenario is the implication that the increase in supply of rough diamonds reaching the market may outstrip demand, at least on occasion, and that new diamond jewelry markets must be developed continually. It is difficult to predict when the full impact of these changes in the diamond industry, all of which are based on the premise that increased geological knowledge will result in important diamond discoveries at an accelerated rate, will have their full impact. Nevertheless, we suggest that it will be at least 20 years in the future. In the future, rather than geological knowledge being "a" key to the future of the diamond industry (see the title of this article), it may be "the" key to the future of the diamond industry.

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