Report R64/2007

MINERAL ABRASIVES IN SOUTH AFRICA 2007

DIRECTORATE: MINERAL ECONOMICS

mineral resources

Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

Report R64/2007

MINERAL ABRASIVES IN SOUTH AFRICA

2007

DIRECTORATE: MINERAL ECONOMICS

Compiled by: Patrick Maseko
E-mail: patrick.maseko@dme.gov.za

Issued by and obtainable from
The Director: Mineral Economics, Mineralia Centre,
234 Visagie Street, Pretoria 0001, Private Bag X59, Pretoria 0001

Telephone (012) 317-8538, Telefax (012) 320-4327
Website: http://www.dme.gov.za

DEPARTMENT OF MINERAL RESOURCES

Director-General	Adv. S. Nogxina

MINERAL POLICY AND PROMOTION BRANCH

Deputy Director General	Vacant

MINERAL PROMOTION CHIEF DIRECTORATE

Chief Director	Mr. S. Sikhosana

DIRECTORATE: MINERAL ECONOMICS

Director	Mr. M. Mabuza
Deputy Director: Industrial Minerals	Ms. N. Dlambulo

THIS IS THE FIRST EDITION PUBLISHED IN AUGUST 2007

ISBN:

TABLE OF CONTENTS

TABLES

ADDENDUM FIGURES

ADDENDUM PHOTOGRAPHS

Introduction

Abrasives – is a term given to minerals used for grinding, polishing and grafting of surfaces. There are various types of abrasives that are used within the South African industry namely; industrial diamonds, garnets, corundum, silica, feldspar, silicon carbide, and tungsten carbide.

Ninety percent of abrasives in South Africa are used in the mining industry, dimension stone industry and ceramic industry. The most common minerals used for hard rock drilling is natural and synthesised diamonds; tungsten carbide. Silicon carbide and fused silicon oxide are used for hard surface polishing and metal polishing.

In terms of world product capacity, in 2004 and 2005, the USA and Canada were leaders in both fused aluminium oxide and silicon carbide at 60,400kt and 42,600kt respectively (See ***Addendum Table 1***). Tons of imported abrasives from the US are declining especially silicon carbide and fused aluminium oxide. This drastic decline is due to adequate availability of resources in the southern hemisphere. In 2002, South African imports of silicon carbide and aluminium oxide from the European countries totalled 744kt compared to 522kt in 2004.

1. Natural Abrasives

Particles are normally bonded together by glue or a certain type of resin which holds them tightly embedded on the hard paper or board. The natural abrasives discussed in this report include industrial /uneconomic/ natural diamonds, garnets, corundum, silica sands, zirconium oxide, silicon carbide and tungsten carbide.

1.1 Industrial Diamonds

These are diamonds that are flawed and badly twinned[1]. Sometimes they have unsightly colour with too many inclusions[2] and 'popcorns[3]' to be cut into gems, hence are being used in industrial applications.

- ***Uses***

Due to unique hardness and tenacity, these diamonds are suitable for manufacturing of diamond-drill bits (for hard rock drilling), diamond tipped cutting blades (for cutting blocks of rock in dimension stone industry), dies for the drawing of wires and polishing powders (fine ground diamonds) for glass, lenses, gems, polishing of specimen for microscopy and also diamonds.

Synthetic diamonds and manufactured abrasives, such as cubic boron nitride, fused aluminium oxide and silicon carbide, are the only materials that can compete with industrial diamonds.

- ***Demand for Industrial Diamond***

World demand for industrial diamond has declined due to substitution by synthetic diamonds.

The demand for industrial diamond in South Africa dwindled in mid 1990's due to the closure of several mines caused by the fall in price of gold. This affected the demand of industrial diamonds in the drill bit manufacturing. However, in 2003, prices of precious metals rallied upward leading to reopening of mines and new operations.

[1]*Two or more diamonds attached together through symmetrical axis.*

[2]*Metals found inside diamonds that acted as substrate/catalyst during growth.*

[3]*Cluster of diamonds bonded together that cannot be easily separated except by breaking*

Consequently the demand for industrial diamond increased. In 2005, South Africa produced 12.2% carats of production of industrial diamonds compared to 13% in 2004. In 2006 the price was stable at R4554/kg.

1.2 Garnet

Garnet is a brittle, transparent to subtransparent mineral, which has a vitreous lustre without cleavage and may have various colours, the most common being red (Hardness 7). Angular fracture and high resistance to chemical and physical attack are qualities that determine garnet as a suitable material to be used in abrasives.

There are six well-known important end members of the garnet substitution field, namely; pyrope often used as gemstone in jewellery; almandine the most common and widely used in the manufacture of sand paper, cloth abrasive and bonded abrasive; green grossular is also used for jewellery; spessartine also used as gem-quality material; andradite often compared to diamond because of its dispersion that even exceeds diamond: and uvarovite which is only used as a gem.

Low-quality garnet is used for sand blasting and for cleaning soft metals like aluminium. Air craft, motor-vehicle and rail coach-manufacturing are major consumers of this type of garnet. Good quality garnet is used as raw material for grains or powders used during grinding and lapping, where high quality finishes are required.

Substitutes for garnet are quartz sand, synthesised diamonds, silicon carbide, fused alumina, chilled iron shot, quenched smelter slag and cerium oxide.

- **Uses**

Garnet is classed as a hard abrasive and has a sharp angular fracture which makes it difficult to fracture. Once it is fractured, a sharp angular point is created thus making garnet a suitable abrasive for rough surface. Another new non-abrasive application is water filtration; since the material is immune to chemical and physical breakdown during filtration and back flushing. The near-spherical shape crystals form a near-size porosity which makes garnet a suitable filtration medium.

The relatively loose coarse grain sizes find application in stone sawing and surface and rough grinding of plate glass. Finer material is being used in rough polishing of lenses, building stone, plate glass, gems and the dressing and the polishing of wood.

- **Production, Trends and Consumption**

Australia is the major producer of garnet followed by India, the US and China while Canada is one of the major suppliers in the world. The US has significant reserves of garnets (***Table 1***).

- **Supply and Demand**

The demand in garnet is strong in jewellery and weaker in abrasive uses and water filtration. In road construction, garnets cannot be used as filler due to its sharp breaking habit.

Garnet deposits are located in Chile, Czech Republic, Pakistan, South Africa, Spain, Thailand and Ukraine. Small-scale mining has been reported in most of these countries.

Although South Africa does not produce garnets in large quantities, Blastrite and Genpaco Limited are major producers of garnet products in the country. Currently, the price of garnet in the South African market is R2500/t. Blastrite is the leading supplier of abrasives in South Africa and sells 3000 metric tons per annum.

Table1. World Production, Reserves, and Reserve Base (Garnet)

	Mine Production (Kt)			
	2004^{e}	**2005^{e}**	**Reserves**	**Reserve Bases**
United States	28,400	28,400	5,000,000	25,000,000
Australia	150,000	155,000	1,000,000	7,000,000
China	28,000	29,000	Moderate –large	Moderate-large
India	64,000	65,000	90,000	5,400,000
Other Countries	31,000	34,800	6,500,000	20,000,000
World total (rounded)	**301 000**	**312 000**	**Moderate**	**Large**

^{e} - Estimate *Source: USGS*

1.3 Corundum

In South Africa, corundum was first recorded in 1904 when its presence was noted east of Mica siding near Phalaborwa in the Limpopo Province, Mpumalanga Province and the Northern Cape Province. The outbreak of the First World War stimulated the exploitation of corundum in the Limpopo Province as it was used as raw material for abrasive for polishing of shell cases and gun barrels.

Pure corundum is colourless, but usually traces of other elements add colour the material. Sapphire is one of the rubies that describe all varieties of corundum other than the red colour.

- **Resources and Exploitation**

Corundum forms in a variety of geological environments. The deposits in South Africa where most production has been derived in the past typically occur in the Limpopo

Province (the deposit is known to contain as much as 5 000 – 10 000 tons of material) in high-grade metamorphic rocks of Achaean age near Palaborwa, Pietersburg, Leydsdorp District, Soutspanberg and Messina. In Mpumalanga Province, the deposits are located in southeast of Piet Retief.

Though largely obsolete as an abrasive, these deposits may yet provide a source of refractory alumina if found in sufficiently large quantities – the pegmatite fields of the Northern Province still appear to have some more economic potential.

Exploitation is by hard-rock mining usually by standard open pit methods; eluvial deposits by hand digging and sorting. Processing involves crushing with jaw crushers followed by a hammer mill and screening.

- **Uses**

In the US, corundum has been used as a burnishing and finishing material. However, since the need for a higher grinding speed, a switch to synthetic material was preferred.
Gem-quality stones are always faceted whereas poorer quality material is used as abrasives. The appearance of rubies and sapphires is sometimes enhanced by artificial processes including heat treatment, surface diffusion, irradiation and fracture filling. Many of the stones seen in the trade are actually synthetic corundum manufactured by the [1]Verneuli process. Rubies are also imitated by red glass, synthetic spinel, garnet and composite stones with natural and/or synthetic parts.

[1]*Synthesis of gem-quality stones by immersion*

In South Africa and India, where there is an abundance of local supplies, corundum has been used in grinding wheels, coated abrasives, abrasive grains and refractories, as well as non-slip treads. Since corundum is the second hardest known mineral after diamond, its use over the past years has expanded towards polishing, lapping abrasive and filler or friction powder. For other various uses see ***Addendum Table 2.***

- **Production and Sales**

Although in South Africa the supply is abundant, production of corundum has dramatically declined since 1984 due to substitution particularly by synthesised abrasive minerals. In years following 1912, South Africa was the prominent producer of corundum with most of it coming from the Limpopo Province. After 1980, where production peaked to 140 tons, production has fluctuated over the years, and recently less than 5 tons are produced (***Figure1***).

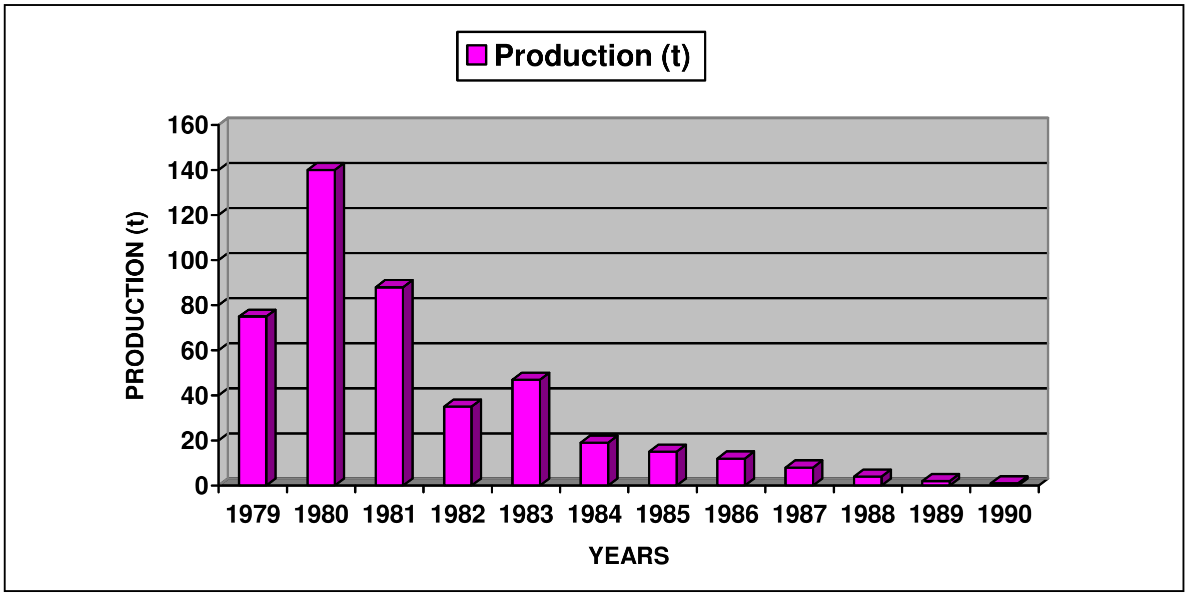

Figure 1. ***Broad trends of corundum production in South Africa.*** *Source: Mineral Bureau*

The price of corundum increased from R38/t in 1957, to R72/t in 1972. Currently the price for crushed and screened corundum sells approximately at R510/t. Finer material from -65mm to dust sells for an average of R350/t.

In the past, Cullinan Minerals imported corundum from Concession Minerals in Zimbabwe. After Cullinan Minerals were taken over by Samrec, corundum production ceased because Samrec was interested in andalusite, bentonite and other special clays hence the supply for corundum dropped over the years and a switch to other materials took place.

A small operator (Northern Corundum) in Rubbervale a few kilometres from Northwest of Gravelotte, imported Zimbabwean corundum, processed it and sold it to the market. It is not recorded whether this company still exists since there are no records kept about its operations.

- **Exports and Imports**

The producers listed in ***Table 2*** below are also modest exporters of corundum and emery. The US imports modest tonnages of corundum from South Africa lumped in a category dominated by garnet while gems including emeralds are imported from India, Brazil and Columbia.

Table 2. Corundum Trade

Producers	Importers	Exporters
Zimbabwe	Canada	Zimbabwe
South Africa	France	South Africa
India	Germany	
Japan		
Netherlands		

Source: The Industrial Mineral HandyBook, by P.W. Harben

- **Supply and Demand**

Towards 1981, mining of corundum in South Africa declined (***Figure 1***) as a consequence of the introduction of a better quality, lower cost synthetic material. However, small quantities are still mined as by-products and exported to the European countries (**Table 2**). Currently, world capacity of corundum is well above 60 000t combined (non-gem variety).

1.4 Silica

There are four categories of silica that are well known but only three of them will be discussed in this report since they are commonly used as abrasives in different applications.

Industrial Sand and Gravel

Industrial sand and gravel, often called “silica”,” silica sand” and “quartz sand” includes sands and gravels with high silicon dioxide (SiO_2) content. These sands are used in glass making; for foundry, abrasive and hydraulic fracturing applications; and for many other industrial uses.

In 2000, total world production declined by 1.7% to 28.4 million metric tons compared with 28.9million metric tons in 1999 due to economic slump caused by recession. However, the decrease was short-lived as demand for sand, not as an abrasive, in the construction industry started to increase exponentially.

- **Supply and Demand**

The United States is the world’s leading producer and consumer of industrial sand and gravel, followed in descending order by Germany, Austria, Spain and France. It is not easy to collect definitive figures on silica and gravel production in most nations because of the wide range of terminology and specifications from country to country.

In 2005, the US increased its mine production of industrial sand and gravel by 5,4%, from 29,700 tons in 2004 to 31, 300 tons. In the same period South Africa ranked 10th in world production, had experienced no increases in production.

Substitutes for sands and gravels are chromite, olivine, staurolite, and zircon sands.

- **Local Demand and Sales**

Since 2004, the demand for gravel and sand was minimal due to decreased demands from the construction industry. However, after the approval of several infrastructural projects (the Gautrain Project, the building of stadia and infrastructural development), the demand is expected to increased exponentially.

1.4.2 Silica Stone

Silica stone products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock.

The domestic consumption of special silica stone is a combination of craft, household, industrial and leisure uses. Major household uses include the sharpening of knives, and other cutlery, such as lawn and garden tools, scissors and shearers. Other uses include polishing of metal surfaces and sharpening and honing of cutting surfaces. Also, silica stone files are used in the manufacture, modification and repair of firearms.

1.4.3 Tripoli

Tripoli comprises of extremely fine grained crystalline silica in various stages of aggregation. Commercial Tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending upon the percentage of iron oxide.

Tripoli is used in abrasives and as filler in the construction industry. World consumption of processed Tripoli decreased by 3% in quantity of to 80 100 tons. In value it decreased by 4% to $10, 5/t (R71.71/t) in 1994. Since then there was no authentic figures of world production have not been readily accesible.

2. Manufactured Abrasive

Manufactured abrasives included in this report are synthetic diamonds, silicon carbide, and tungsten carbide.

2.1 Synthetic Diamonds

Synthetic diamonds are diamonds that are manufactured under **H**igh **P**ressure (5 - 6GPa) and **H**igh **T**emperature ($\pm$ 1500^{o}C), HPHT, by employing presses consisting of two anvils (top and bottom) and one central die.

The manufacturing of diamonds started in Russia in the early 1950s and has improved over the years. Recently the quality of synthesised diamonds has dramatically improved. It is now difficult to differentiate, with a naked eye, between a natural and a synthesised diamond, unless a diamond tester is used. Through advanced technology, the production process is controlled in terms of temperature and pressure and residence time in the press, depending on the end-user's requirements.

The first commercially successful synthetic diamond was produced in December 16, 1954, by H. Tracy Hall at General Electric, using an elegant "belt" apparatus. This gave rise to an industrial diamond industry that was for decades represented by two main players: GE Superabrasives and De Beers Industrial Diamonds. Afterwards new competitors emerged from Korea named Iljin Diamond, followed later by hundreds of Chinese entrants. De Beers is still regarded a world leading supplier of synthetic diamonds and Carbon Boron Nitride, cBN.

Despite being occasionally characterized as 'fake", synthetic diamond is molecularly identical to the carbon allotrope defined as diamond when referring to naturally occurring diamond.

Strength, shape and durability are the main characteristics that determine the quality of a diamond. Most synthetically produced diamonds are small and of industrial quality. The process of producing gem-quality diamonds is very time consuming and expensive, hence it is cheaper to mine them. Over a period of time more and more synthetic diamonds will be seen in the trade.

Cubic zirconia, yttrium, aluminium garnet, strontium titanate, gadolinium gallium garnet and certain glasses are the most convincing in appearance unless detected by the standard gemmological equipment and procedures.

Another type of synthetic diamonds is Chemical Vapour Deposition, CVD, developed. CVD diamond is produced in two forms: CVD single crystals and CVD polycrystalline diamonds. The former is developed from one single crystal diamond substrate whereas the latter is developed from a 3D shape of CVD polycrystalline diamond.

The other important type is the Polycrystalline diamonds (PCD) in conventional rotary drilling for the bulk of oil drilling (***See Addendum Photograph 1***).

- ***Uses***

The mining industry is the major consumer of synthetic diamonds. Synthetic diamonds rather than natural diamonds are used for about 90% in industrial applications. Rock-drilling equipments are strictly manufactured by inserting synthesised diamonds at the edge of the core and fused into the metal.
Since it is still cheaper to produce these diamonds, medical institutions have also switched to diamond designed utensils for surgery and medical uses.

CVD polycrystalline diamonds have a wide field of applications, ranging from abrasive to optical to medical and to environmental. CVD single crystal particle is mainly used in abrasive, electronics, sensor and detector applications.

The motor industry uses poly-crystalline diamonds, PCD, to machine aluminium alloys. PCD diamonds are also used in oil drills and other mining tools.

CVD diamonds have demonstrated their importance in their use as electrodes. Since the diamond is chemically inert, it is used as an electrode under conditions that would destroy traditional materials. For such reasons waste water treatment of organic effluents as well as production of strong oxidants has been developed. There are a number of companies already producing diamond electrodes.

Diamond has also shown great promise as a potential radiation detection device. Since it has a similar density to that of soft tissue, it therefore displays strong radiation and also a wide band gap. Hence its use in medication.

- ***Production and Sales***

Production, sales and export of synthesised diamonds is complex. This is due to the fact that these minerals are not mined like other mineral but are produced in thousands of tons per day in laboratories, plants and factories. Owing to such reasons, it is difficult to account for the whole production.

During the 1990's China flooded the market with cheaper products resulting in closure of other operators. This had forced De Beers to close down some of its production plants overseas and concentrate on one plant based in Springs, in the Gauteng Province, South Africa.

The reopening of some of the closed mines is expected to increase demand for synthetic diamonds particularly the grit type and the powder type. Constant-dollar prices of synthetic diamond products will probably continue to decline as production technology becomes more cost effective. The decline is even more likely if competition from low-cost producers in China and Russia continue increasing.

In 2006, the industrial diamond industry was an annual 1billion dollar (R6.5 billion) market, producing 3 billion carats or 600 metric tons of synthetic diamond.

2.2 Silicon Carbide, SiC

Silicon Carbide is a bluish-black crystalline compound, one of the hardest known substances. It is used as an abrasive and heat-refractory material and in single crystals as semiconductors, especially in high temperature applications. In the market it is known by its trade mark name; carborundum. Man-made product is manufactured by combining silica sand and carbon at a high temperature, between 1600 and 2500 ^{o}C. Silicon Carbide was discovered by E.G. Acheson in 1891.

- ***Uses***

Silicon carbide substitutes more than half of its counter-parts in industry (tungsten carbide, alumina, synthetic and natural industrial diamonds etc.). Silicon, in the compound, reduces undesirable elements into slag whilst carbon combines to form an alloy in the steel manufacturing industry.

In industry it is used in; *semiconductors, structural, astrology, disc brake, diesel particulate, ceramic membrane, cutting tools, heating element, nuclear fuel and jeweller.*

As an abrasive, it is used in a form of grit for lapidary due to its durability and low cost of the material. It is also used in coarse to fine grit sand papers and as a grip tape in skateboards.

- ***Production***

Sublime, situated in Kriel (KwaNala) in Mpumalanga, is the only company that produces silicon carbide in South Africa. Sublime purchases 2 000 t per month (at R100/t) of silica from Samquartz in Delmas. Local customers are Thermal Ceramics, Calderys, Saint Gobain Abrasive and Grinding Techniques.

Currently, in South Africa, there are no other producers of silicon carbide except Sublime. However deposits of silica in South Africa are immense.

2.3 Tungsten Carbide

Tungsten Carbide is an extremely hard, fine grey powder composing of wollastonite, used in tools, dies, wear resistant machine parts, and abrasives. It is a compound that is similar to titanium carbide. Its extreme hardness makes it useful in the manufacture of cutting tools, abrasives and bearings, as a cheaper and more heat-resistant alternative to diamond. It is also used as a scratch-resistant material for jewellery including watch bands and wedding rings.

- **Occurrences of Tungsten**

In South Africa tungsten (also known as wolfram) is located in the Northern Cape, Northern Province, Mpumalanga and KwaZulu Natal. The Northern Province has the majority of deposits in various areas and the most significant tungsten mining is the Springbok-Nababeep area. The area is located almost entirely within the economically important Namaqualand copper district.

South African tungsten deposits are insignificant compared to those of China, South Korea, Commonwealth Independent States (CIS), USA, Canada, Portugal, Austria, Bolivia, Brazil and Australia. In Central and Southern Africa the most economical deposits are found in Rwanda, Burundi, Zaire and Zimbabwe.

- **Uses**

Apart from being used as an abrasive, tungsten carbide is known for its robust hardness in cutting surfaces and machining, especially through other materials such as carbon steel or stainless steel as well as in situations where other tools would wear away since it is more brittle than other tool material. It is not suitable for machining but can leave a better finish on the part and allow faster machining.

In military use it is often used as armour-piercing ammunition, especially where depleted uranium is not available or not allowed.

In sports, it is used on poles which impact hard surfaces such as tracking poles used by hikers, ski pole tips and roller ski tips.

For domestic use, tungsten carbide can be found in the inventory of some jewellers, most notably as the primary material in men's wedding bands.

In fiction, it is mostly used in the video games such as the Halo video game series, magnetic accelerator projectiles. These are coated in a hard outer layer of tungsten carbide.

Because of its high melting point, tungsten carbide finds its application in the manufacturing of light bulb filaments. It is also used in wear-resistant and coatings.

Ammonium paratungstate (APT) is the widely used intermediate product and also the main tungsten raw material that is traded in the market.

- **Substitutes**

Tungsten is the only material used in the light bulb filament. However, there are other experiments that are being conducted with ceramic and ceramic metals to create alternative materials. In abrasives, jewel and cutting tools it is replaced by diamond, silicon carbide and alumina. In the mining industry, diamond drill bits are more preferred because of their extreme hardness and robustness.

Another important factor is that undamaged, chipped-off diamonds can be recovered and new drill bits can be manufactured. Tungsten as a metal carbide tends to melt on hard material and is also recoverable as scrap tungsten.

- **Production**

During the early nineties, China, Commonwealth of Independent States (CIS) and Northern Korea dominated the world tungsten market to such an extent that most western producers were forced to close, either permanently or temporarily. China provides 80% to 90% of the world's supply (world's total is 76 500t). Since 1999, China has been a leader in the world's production of tungsten (***Addendum Table 4***).

However, the elimination of China's tungsten ore and concentrate export in 2004 due to the Commonwealth's countries decision, industry restructuring and stricter environmental regulations have led to a growing tightening of supply.

Currently, Vietnam has a developing plant that produces tungsten, once the plant comes into full production; it will be the world's largest producer of tungsten outside China (approximately 10% of global supply).

South African tungsten deposits are insignificant compared to those of China, the CIS and other European countries, thus most of the raw material is imported from these countries. Major producers of tungsten carbide in South Africa are quite few, Kram-welding, operating under EngNet South Africa, Boart S.A which has been bought recently by Element Six and others. Kram-welding receives scrap tungsten carbide (APT form) and reproduces tungsten carbide products.

- **World Development**

World tungsten production dropped from a peak of over 55 000t of metal contained in 1990 to just over 30 000t in 1997, it peaked again to an estimated 76 500t in 2005 as the European countries were coming out of an economic recession. A prolonged period of relatively low prices for tungsten had forced many western producers out of the market, while the break up of the former Soviet Union (USSR) led to a collapse in tungsten production in that region. In periods of strong demand, the deficit between production and demand for tungsten has been made up in sales from the stockpile.

China the world's largest producer and exporter of tungsten ores and concentrates, and of intermediate and finished tungsten products account for 80% of the annual world market which is around 80 000t. In June 2006, the Chinese government announced closure of several mines from a total of 28, in the provinces of Jiang Xi, Hu Nan and Guangdong. These provinces have an output production of 60% of the Asia.

- **World Market**

In 2004, the tungsten market was unstable in response to increased demand from the booming North American economies, European countries and from Japan coming out of recession. In the same year the prices gradually increased from a low of US$27/metric ton units (R193) at the start of the year and peaked at high of US$60/metric ton units (R428) in November the same year.

In 2005, tungsten prices had soared by 22% to trade at US$240/mtu (R1714) relative to US$27/mtu in 2004.The widely used ammonium paratungstate (APT) had risen remorselessly in 2007 to US$260/mtu (R1856) from a low of US$180/mtu (R1285).

In 2002, South Africa imported 2 metric tons of tungsten metal powder at a value of $89 000 (R614 100). In 2003, South Africa imported 1 metric ton at a value of $21 000 (R144 900).

In 2002, South Africa imported 11 metric tons of tungsten carbide powder from the US valued at $152 000 (R1 048 800); followed by 56 metric tons in 2003, at a value of $625 000 (R4 312 500). The largest consumer of tungsten (especially APT) is believed to be EngNet South Africa who produces tungsten carbide.

Total tonnage data of tungsten material entering South Africa is not yet available especially the material that comes from China, Canada, Japan and Russia. In 2002, the US imported 56 metric tons of miscellaneous tungsten-bearing materials from South Africa at a value of R1 904 ($272) and in 2003, 60 metric tons at a value of R2 506 ($358). South Africa does not have a well established market of tungsten except for tungsten carbide and its final products.

OUTLOOK

The synthetic diamond is a definite threat to the gem diamond market. The comparison can be made with other created gems. The scarcity of man-made diamonds still commands a high price. However, in the case of natural stone production, the wholesale is in the range of $ 50,000/ct for 1 to 2 carat size stones.

In recent years, there has been a drastic change in ownership in this industry. In 2002, De Beers Industrial Diamonds rebranded to Element Six in Springs, Gauteng Province and is operating independently from De Beers. This change did not affect the sale and production of synthetic diamonds. In 2003 General Electricity (GE) sold GE Superabrasive to Littlejohn and it was named Diamond Innovations, who in turn sold it to Sandvik in January, 2007.

Many more international companies have become important players in the industrial diamond market. These include Sumito Electric Hardmetal, US Synthetic, Smith Megadiamonds, Apollo Diamond, Gemesis, Tairus and Diamond Essence.

Tungsten is not mined in South Africa but there are many companies that manufacture tungsten carbide products such as EngNet, Navarro SA, Umico SA and Wheelabrator SA (Metabrasive). Most of the products are made overseas and imported as finished products into South Africa.

Capacity expansions by numerous producers in other products are likely to lead to higher production of the minor minerals for the next five years. These expansions depend upon the continuation of the broad-based increase in world demand for minerals as South Africa is bracing itself for a sound economic boom. Factors that will inhibit these plans include the strength of the South African rand and the ever-glaring HIV infection in the mining workforce.

CONCLUSION

By virtue of its wealth of mineral resources, South Africa is the leading producer and produces over 45% of the world's of chrome –ore , vanadium, vermiculite and many more, but insignificant in producing end-products.

Economical contribution of abrasives in South Africa is not well defined since most of the finished products come from European countries particularly Germany, and others like Japan, United States and China.

South Africa is loosing billions of rands from its own raw material. Raw material is exported at lower prices and sold back later as finished products at very high prices. This has an impact to the country's economy and increases the country's high rate of unemployment.

ADDENDUM TABLES

Table 1. World Production Capacity (Silicon Carbide vs Fused Aluminium Oxide)

	Fused aluminium Oxide		**Silicon carbide capacity**	
	2004	**2005^{e}**	**2004**	**2005 ^{e}**
United States and Canada	60,400	60,400	42,600	42,600
Argentina	-	-	5,000	5,000
Australia	50,000	50,000	-	-
Austria	60,000	60,000	-	-
Brazil	50,000	50,000	-	-
China	600,000	600,000	455,000	455,000
France	40,000	40,000	16,000	16,000
Germany	80,000	80,000	36,000	36,000
India	40,000	40,000	5,000	5,000
Japan	25,000	25,000	60,000	60,000
Mexico	-	-	45,000	45,000
Norway	-	-	80,000	80,000
Venezuela	-	-	30,000	30,000
Other	80,000	80,000	190,000	190,000
World Total (Rounded)	**1,090,000**	**1,190,000**	**1,010,000**	**1,010,000**

^{e}Estimate *Source: Mineral Industry Survey, USGS*

Table 2. Summary of the various uses of corundum.

Application	Comments	Specifications
Abrasive, lapping, polishing and tumbling media	Market very small, synthetic materials last longer and are more consistent. Polishing of lenses.	General requirement: *Physical Properties:* Hardness, should break with uneven splintery surface.
Non-skid flooring	Corundum hardness and sharp conchoidal fracture ideal for this application	*Chemical properties:* Al_2O_3 > 80% Fe_2O_3 < 4% Low H_2O content
Safe linings	Was used as an aggregate in aluminium metal for safe linings; market is declining	
Refractories	Calcined corundum is for considerable use in shaped and monolithic products	*Aggregate sizes:* 22 + 16 mm 16 + 6 mm 6 + 2 mm - 2 to dust (Purbrick 1991)
Concrete	Abrasion-resistant concrete for lining ore passes in mines	
Cement	Corundum as a cheap source of Alumina in high-alumina cements.	

Source: The Mineral Corundum Resources of South Africa

Table 3. Properties of some garnet end members.

Variety	Formula	Hardness	SG	Colour
Almandine	$3FeO.AlO_3.3SiO_2$	7.5	3.9 – 4.2	red, brown, black
Grossular	$3CaO.Al_2O_3.3SiO_2$	7.0	3.5 – 3.7	white,green,yellow
Pyrope	$3MgO.Al_2O_3.3SiO_2$	6.5–7.5	3.5 - 3.8	red, black
Spessartine	$3MnO.Al_2O_3.3SiO_2$	7.0–7.5	4.1 – 4.3	brown, red
Andradite	$3CaO.Fe2O_3.3SiO_2$	6.5–7.0	3.7 - 3.8	black,green,yellow
Uvarovite	$3CaO.Cr_2O_3.3SiO_2$	7.5	3.4 – 3.5	green

Source: The Mineral Resources of South Africa.

Table 4. World Production of Tungsten

Country	1999	2000	2001	2002	2003
Austria	1 610	1 600[e]	1237	1 400[e]	1 400
Bolivia	334	382	533	400[r]	442[e]
Brazil	13	18[r]	22[r]	24[r]	25
Burma[4]	87	74	48[r]	30[r, e]	30
Canada	-	-	-	2 550[e]	2 750
China[e]	31 100	37, 000	38 500	49 500	52 000
North Korea[e]	500	500	500	600	600
Mexico	11	-	-	-[e]	-
Mongolia[e]	27	52	63	35[e]	40
Portugal	434	743	698[r]	693[r]	700
Russia[e]	3 500	3 500	3 500	3 400	3 900
Rwanda	41	108	142[r]	153[r]	150
Thailand[e]	30	30	53[r]	30	30
Uganda	(5)	-	17	16[r]	10
	37 700	44 000	45 300	58 800	62 100

e – Estimate *Source: US Geological Survey Minerals Yearbook, 2003.*

r – Reserve

ADDENDUM FIGURE

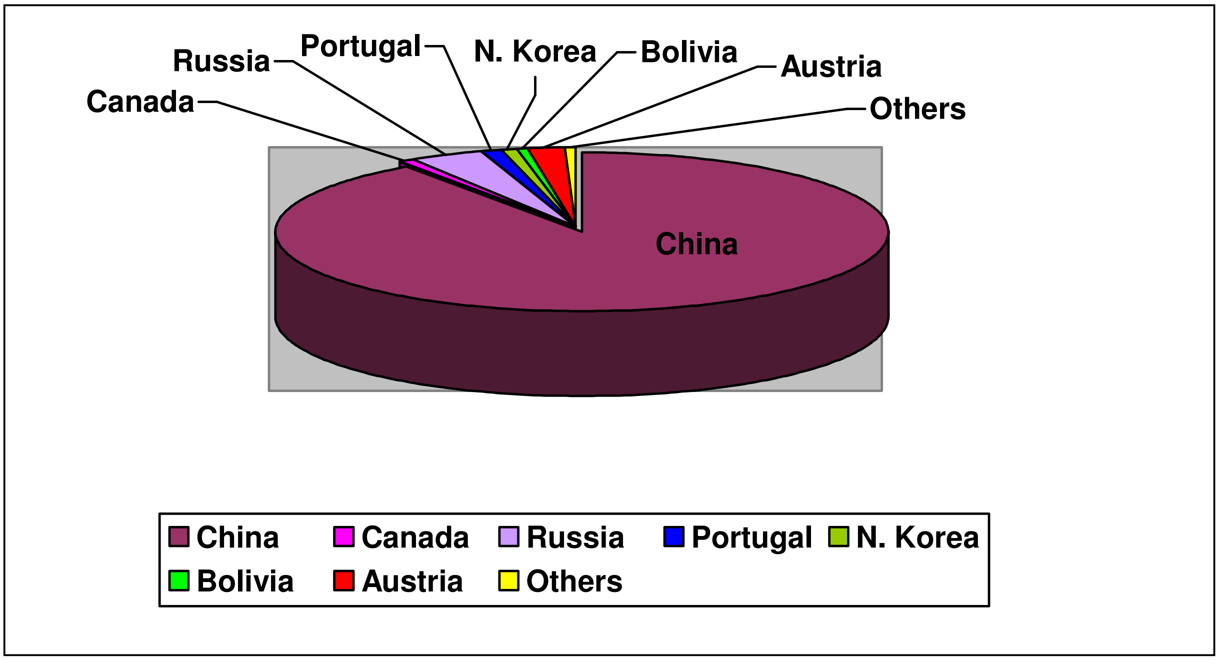

Figure1. World Production of Tungsten.
Source: http://www.primarymetals.ca/s/TungstenMarket.asp

ADDENDUM PHOTOGRAPH

Photograph 1. PCD Drills used for oil and well drilling. *Source: http://www.e6/page.jsp*

REFERENCES

The Mineral Resource of South Africa, *by M.C.G Wilson*, C.R Anhaeusser.

The Mineral Industry of South Africa, *by Thomas R. Yager.*

Mineral Industry Survey*, USGS*

The Industrial Minerals HandyBook*, by Peter W. Harben.*

Material Technology Publications, internet: *www.mat-tech.co.uk*

Mintek chemical analyses report, 2004

Nepheline Syenite, Arkansas Geological Commission:
http://www.state.ar.us/agc/nephelin.htm.

Nepheline Mineral Data: http://*www.webmineral.com/data/nephelin.shtml.*

Feldspar and Nepheline Syenite*:http://www.minerals.usgs.gov.minerals/pubs/*

South African Geology, *Jos Lurie 1986.*

SAMI, 2005/2006