REPORT R55/2008

AN OVERVIEW OF SOUTH AFRICA'S VANADIUM INDUSTRY DURING THE PERIOD 1997 - 2006

DIRECTORATE: MINERAL ECONOMICS

mineral resources
Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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DIRECTORATE: MINERAL ECONOMICS

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ISBN: 978-1-919927-81-7

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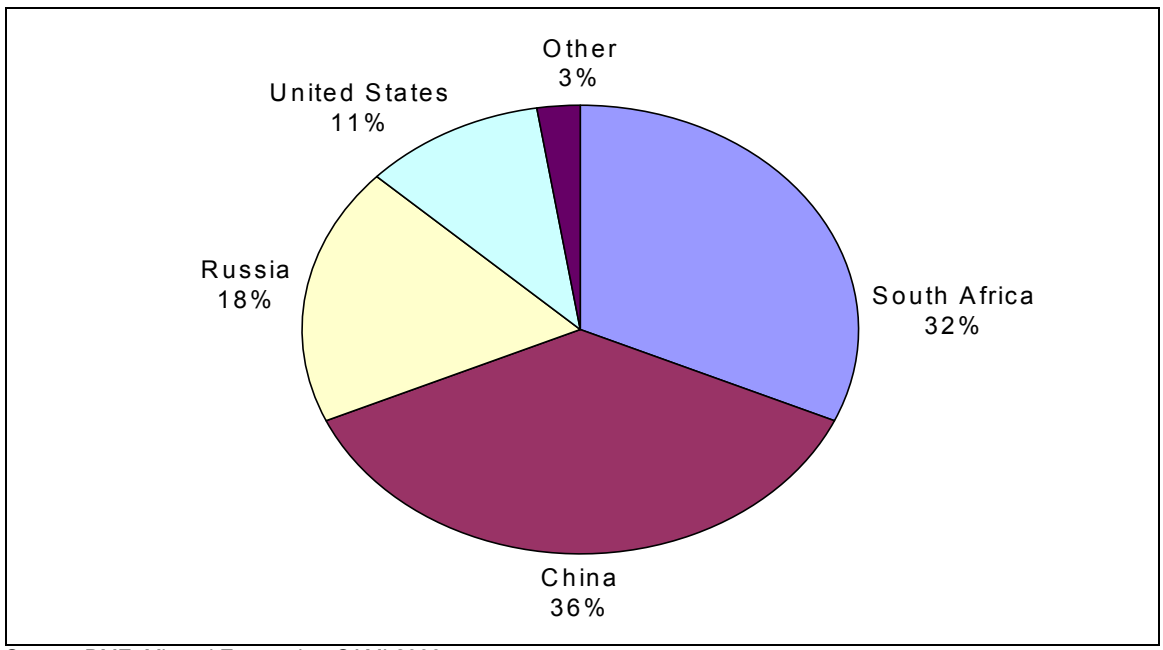
1. INTRODUCTION

Although vanadium is the thirteenth most common metallic element, it is perceived to be one of the rarest elements in terms of crustal abundance. Its rarity is due to fact that, despite being widely distributed, concentrations are low. Vanadium can be produced from a number of sources. It is mainly associated with the titaniferrous magnetite deposits, the bulk of which is hosted in the upper zone of the Bushveld Complex of South Africa (Annexure 1). Other sources include uranium ore, phosphorous ore, crude oil, power plant ash and slag.[1]

The Bushveld Igneous Complex runs across the North-West, Limpopo and Mpumalanga Provinces, and is also a dominant host of Platinum Group Metals (PGM's) and Chromite deposits. Due to the scarcity of the vanadium element, exploitable values of less than 1,5 percent vanadium are found in South Africa's magnetite deposits. Exploitation of vanadium in South Africa dates back to 1957 at Witbank, in the Mpumalanga Province[1].

World vanadium reserves amounted to 27 Mt before 2002, dominated by South Africa, which then accounted for 44 percent (12 Mt). However, in 2002, new information confirmed additional reserves of 11 Mt from China, boosting its vanadium reserves and world reserves to 14 Mt and 38 Mt, respectively. Consequently, South Africa became the second largest host of vanadium after China, accounting for about 32 percent of the reserves (Fig 1).[2]

Figure 1: Global Vanadium Reserves, 2006



Source: DME, Mineral Economics, SAMI 2006.

2. VANADIUM OPERATIONS IN SOUTH AFRICA

There are three primary vanadium producers in South Africa. Of the three; Highveld Steel and Vanadium Corporation is the largest, followed by Vametcor and Rhovan at distant second and third place, respectively.

Highveld Steel and Vanadium Corporation's Vanchem plant sources the magnetite ore from the Mapochs mine in Mpumalamga, and 20 percent vanadium-bearing slag produced from the steel making plant. The operation has a total capacity of 11 000 tonnes per annum (tpa) of V_2O_5.[4] In 2007, the Russian steel producer, Evraz, acquired 79 percent of the Highveld Steel and Vanadium Corporation. However, the European Union and South African competition authorities approved the deal on condition that the vanadium business be disposed of in order to minimize Evras's dominance of the market. [3]

Vametcor, a subsidiary of Strategic Minerals Corporation of USA (Stratcor), in which AKA Resources owns 13 percent stake, produces nitrovan (a nitrated vanadium alloy) at its 6,5 tpa facility in Brits, in the North West Province, where it

operates a captive mine. [6] However, due to depletion of the economic reserves, the mine has not been able to satisfy Vametcor's growing demand for ore, as a result of which slag from Highveld is used to upgrade the ore.[4] Stratcor is 73 percent owned by Evraz, [6] this is part of the reason the vanadium business acquired from Highveld had to be disposed of, to minimize Evras's dominance in the vanadium industry.

Rhovan is part of Xstrata Alloys SA, which sources its titaniferrous magnetite ore from an integrated operation located in Brits. The plant was built in 1997 with the original capacity of 4 800 t of vanadium pentoxide. Through capacity expansion, Xstrata raised production at its Rhovan plant to 9 300 t of V_2O_5 per annum, to make up for the closure of PMA's Windimurra plant in Australia and the exhaustion of ore at Xstrata's Vantech operation in 2003.[4]

3. VANADIUM EXTRACTION PROCESS

Four vanadium products are produced from the magnetites, i.e. Vanadium Pentoxide (V_2O_5), Nitrovanadium (NV), Vanadium in slag and Ferrovanadium (FeV) alloy.

The magnetite ore is first concentrated through crushing, grinding and magnetic separation to produce a magnetic concentrate. The concentrate is then roasted in a kiln to produce a water soluble sodium vanadate, which is then leached with ammonia to produce a pregnant solution containing V_20_5 with high silica content. This is followed by the de-silication process, which removes silica to improve product quality of the pregnant solution. Vanadium is then precipitated from the solution in the form of ammonium vanadate, which is then filtered and de-ammonised. The V_20_5 produced is in a form of a powder, which is not suitable for transportation to customers. Consequently the pentoxide powder is melted in a fusion furnace and formed into flakes. FeV is produced by first reducing the V_20_5 to Vanadium Trioxide (V_20_3) and then reacting this with iron and aluminium to produce Ferrovanadium.[9] (Annexure 2).

4. VANADIUM APPLICATIONS

The general uses of vanadium include metallurgical and chemical applications. Vanadium demand is largely driven by the carbon steel manufacturing industry, which accounts for about 90 percent of world vanadium consumption. [5] Niobium, which has almost similar properties to vanadium, is used as a substitute for vanadium when vanadium prices are very high or when supply is in deficit.

In metallurgical applications, vanadium is used in steel industry for retarding grain growth at elevated temperatures with its affinity for carbon and nitrogen to form carbides & nitrides promoting finer grain size, increased hardenability, imparting high strength and improved wear resistance. Due to these properties, it finds extensive use in High Strength Low Alloy Steels (HSLA), constructional alloy steels, carburizing steel grades, rail steels, heat resisting tool and die steels, creep resistant martensitic stainless steels as well as in forging and cold heading steel grades. Today, HSLA steels substitute carbon steels in many applications which include pipelines, concrete reinforcing bars, structural shapes, flat steels and automobile components as these steels permit lower design weight with increased strength coupled with increased weldability through addition of vanadium. Due to its high temperature strength, vanadium is applied in super alloy industry for making turbine blades and jet engines. It is also used as a stabiliser in titanium aluminium alloys in aerospace industry.

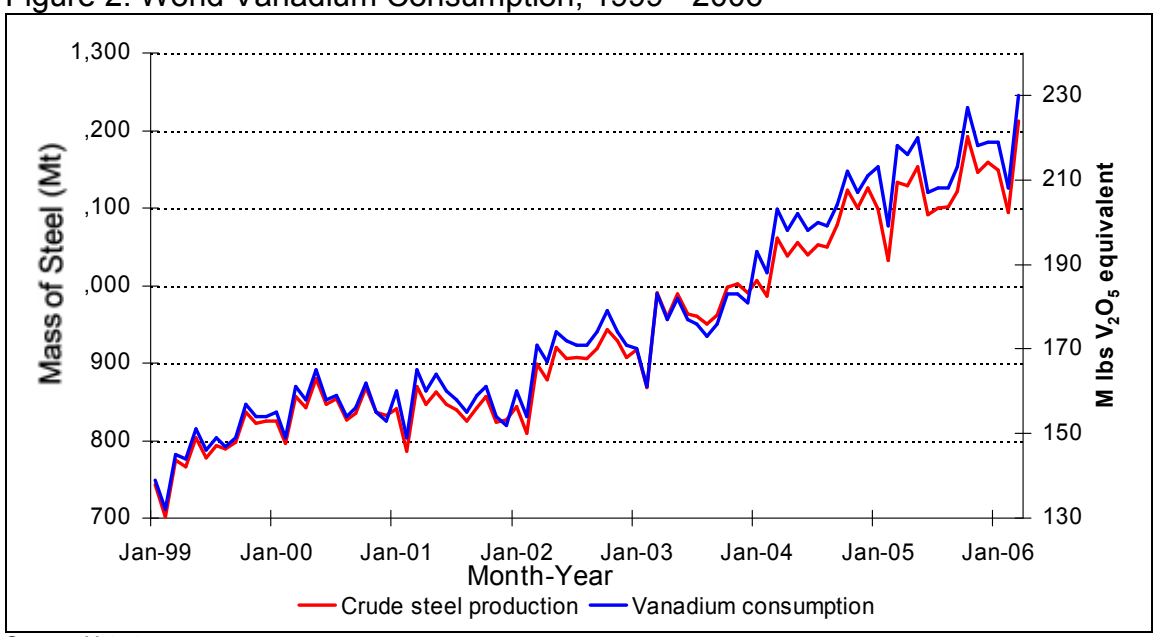
In chemical applications, vanadium compounds are used in oxidation catalysts for the production of sulphuric acids and the cracking of petroleum products in chemical industry. It is also used as a glass and ceramic pigment, in permanent magnets, dryers, paints and varnishes, processing of colour films, small rechargeable batteries and catalysts for the control of exhaust fumes in diesel engines. Vanadium is also used in electro-chemical energy storage systems in a form of Vanadium Redox Flow Batteries, where its ability to store electrical energy as chemical energy is exploited. These batteries act as an excellent back-up energy supply during power outages.

5. GLOBAL SUPPLY DEMAND DYNAMICS

5.1. The Effect of Steel Production on Vanadium

There is a clear correlation between vanadium consumption and steel production (Fig 2). However, vanadium consumption growth was stronger than that of steel production as a result of increasing vanadium consumption per ton of steel in the production of high strength steel alloys, between 2001 and 2006.

Figure 2: World Vanadium Consumption, 1999 - 2006

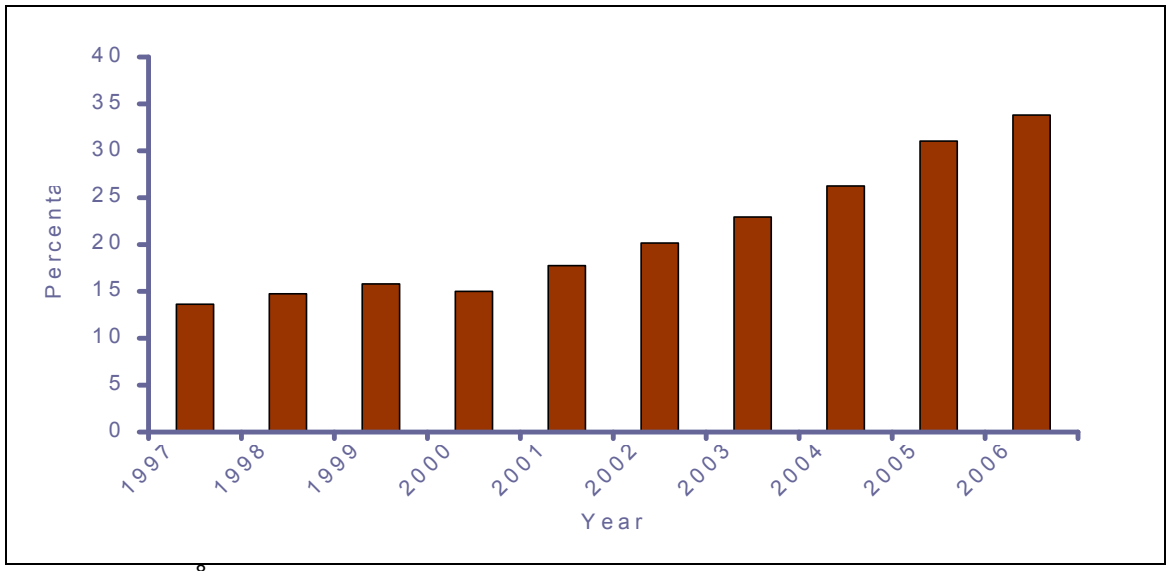


Source: Xstrata

5.2. The China Factor

China, which increased its contribution to world steel production from 13,6 percent in 1999 to 38,5 percent in 2006, is the largest steel producer, followed by Japan at 9 percent and USA at 8 percent. South Africa's contribution is insignificant at less than 2 percent.[8] Since vanadium adds significant load bearing strength in construction steels, Chinese construction authorities require the use of vanadium-added reinforcement bar (rebar) in earthquake-affected areas, which contributes to the increased vanadium demand from that country.[7]

Figure 3: China's Contribution to the Global Steel Output, 1997 - 2006



Source: World Steel[8].

6. SA'S VANADIUM SUPPLY AND CONSUMPTION

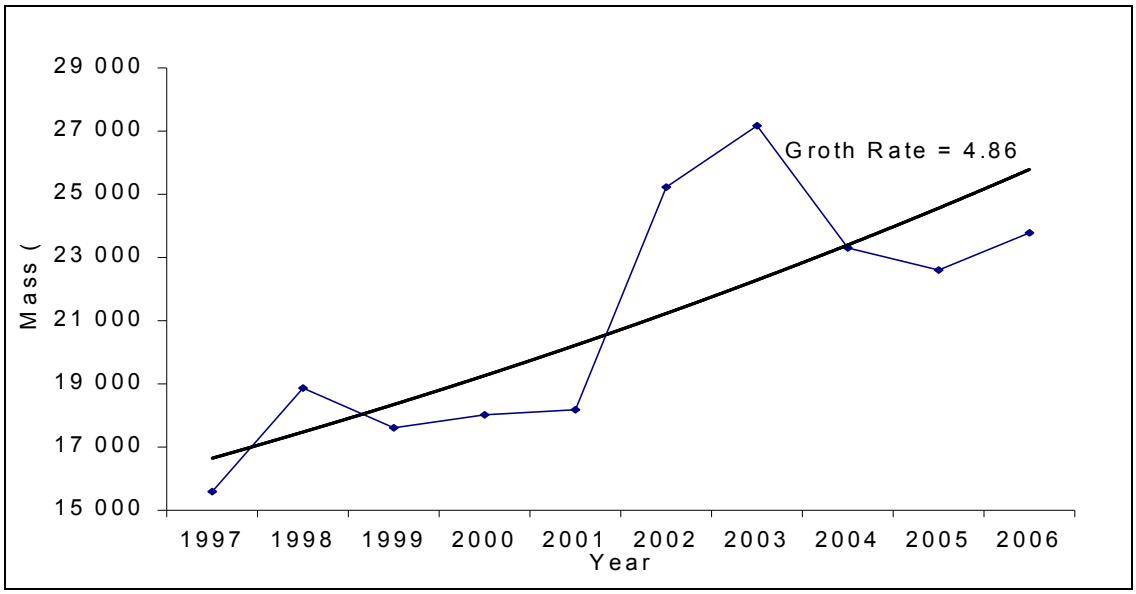
6.1 Supply

- **Production**

South Africa's vanadium production has grown at an average rate of 4,9 percent per annum (Fig 4), as a result of the growing demand from the steel industry. Production increased at an accelerated rate during the second half of the period under study, reaching an average of 24,4 kt, 38 percent higher than the average of 17,7 kt achieved in the first half.

Higher production volumes, which persisted for most of the period under study, were due to new capacity, increased capacity utilization and attractive commodity prices driven by strong demand from the steel industry. The strong growth experienced during 1998 was followed by 7 percent decline in 1999 on the back of lower prices.

Figure 4: SA Vanadium Production, 1997-2006



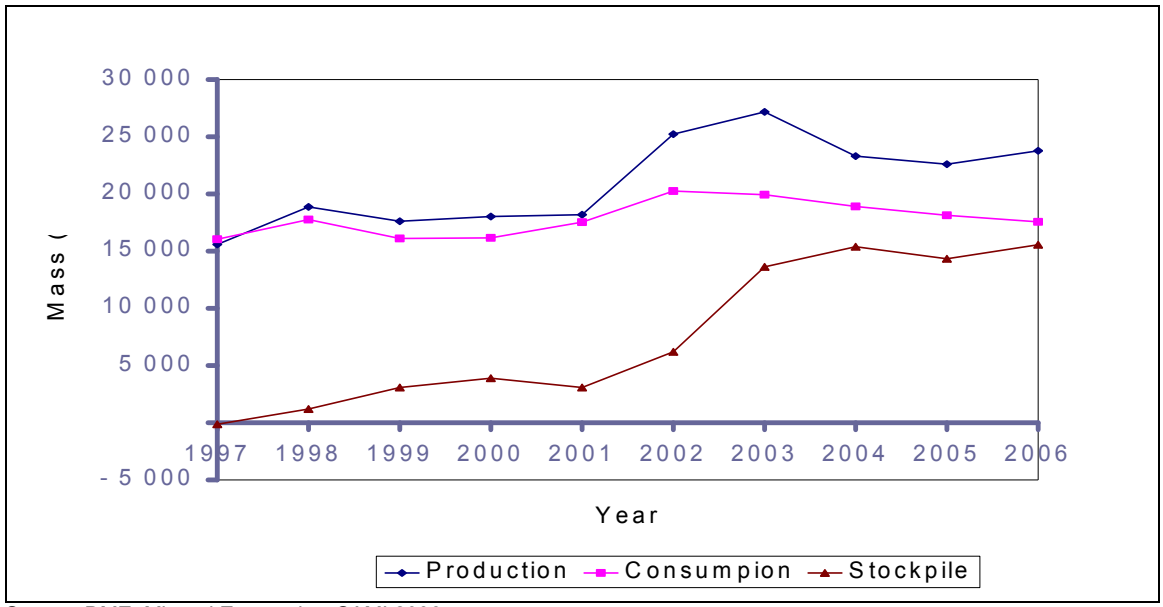
Source: DME, Mineral Economics, SAMI 2006.

By 2002, the market equilibrium was achieved as a result of production cutbacks from previous years and higher demand from China. Consequently, South Africa's vanadium production increased to 25,2 kt that year, followed by a marginal increase in 2003, prompted by the closure of the Windimurra plant in Australia. However, production fell by 14 percent in 2004, as a result of Vantech's (Xstrata) closure and the high inventory levels that had accumulated in the previous year. This downward movement continued at a slower rate in 2005, until the market was brought back to a state of equilibrium in 2006, leading to 5 percent increase in vanadium production.

- **Vanadium Stocks**

Vanadium stocks appear to have been building up in South Africa as production growth became steeper than the sales (Fig 5). Vanadium stocks have doubled from 3 kt in 2001 to 6 kt in 2002, increasing to 14 kt in 2004, while sales volumes increased marginally by 1,5 percent per annum.

Figure 5: SA Vanadium Stock, 1997 – 2006



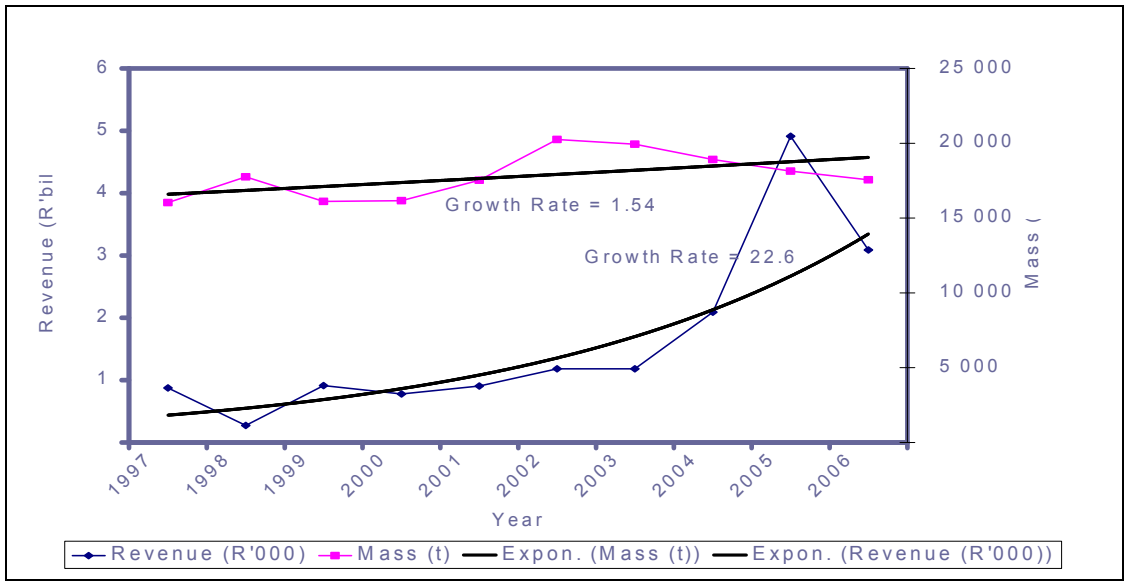
Source: DME, Mineral Economics, SAMI 2006.

6.2. Consumption

- **Total Sales**

South Africa's vanadium sales volumes increased at a rate of 1,54 percent pa, from 16 kt in 1997 to 17,6 kt in 2006. Revenues generated grew by an average of 22,6 percent per annum, from R847 million in 1997 to R3,09 billion (Fig 6) in 2006. The sales revenue remained more or less stable until 2003, after making a good recovery in 1999. Revenue increased by 33,5 percent between 2004 and 2005, as a result of steep rise in prices (Fig 7).

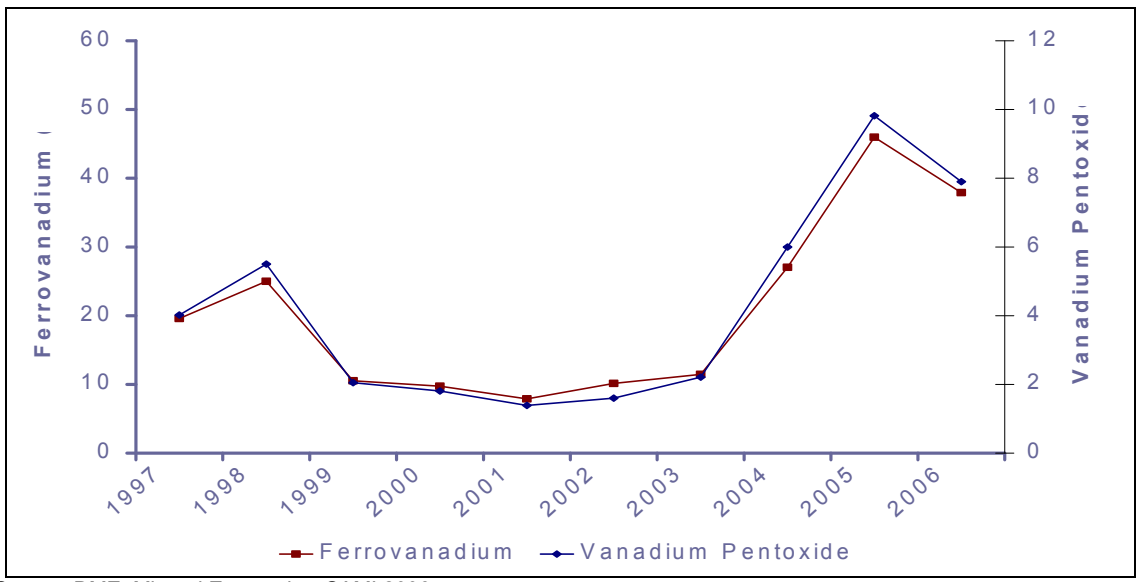
Figure 6: SA Vanadium Total Sales, 1997 - 2006



Source: DME, Mineral Economics, SAMI 2006.

Vanadium prices rose by an average of 9,6 percent pa from 1997 to 2006 (Fig 7), rising steeply, particularly in 2004 and 2005, with pentoxide price increasing from $6 per pound (lb) in 2004 and peaking at $9,8 lb in 2005. A combination of higher vanadium demand from steel producers and more stringent regulations in China requiring higher levels of vanadium usage in construction projects in that country, contributed to the rising prices.

Figure 7: Vanadium Prices, 1997 – 2006

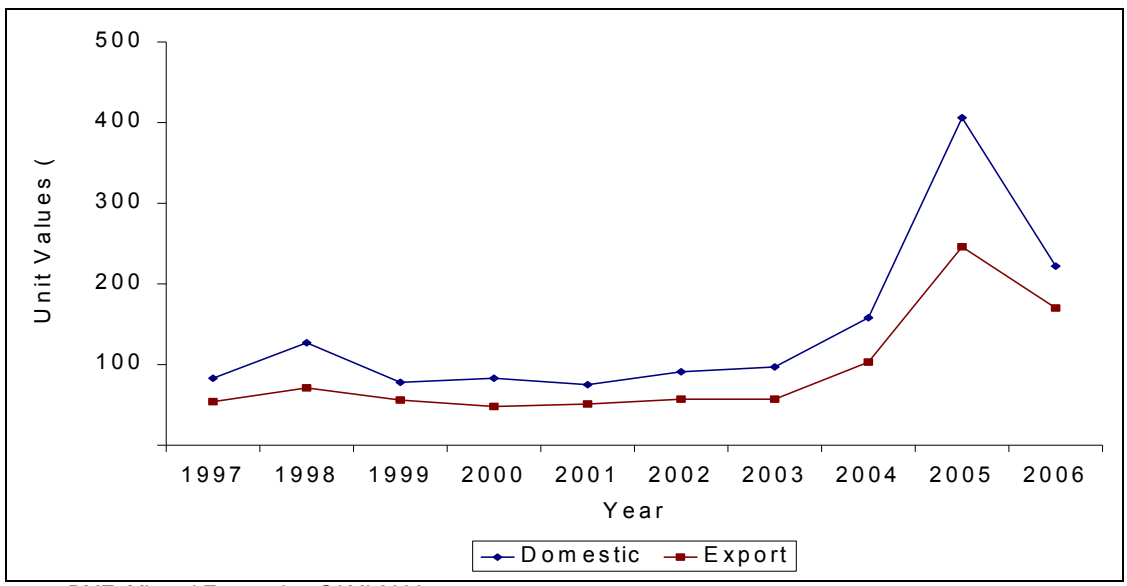


Source: DME, Mineral Economics, SAMI 2006.

These high prices for vanadium products in 2004 and 2005 encouraged uneconomic producers to increase their productivity, putting a downward pressure on prices during 2006, leading to a slow down on South Africa's sales.

- **SA Vanadium Unit Values**

Figure 8: Unit Values, 1997 – 2006



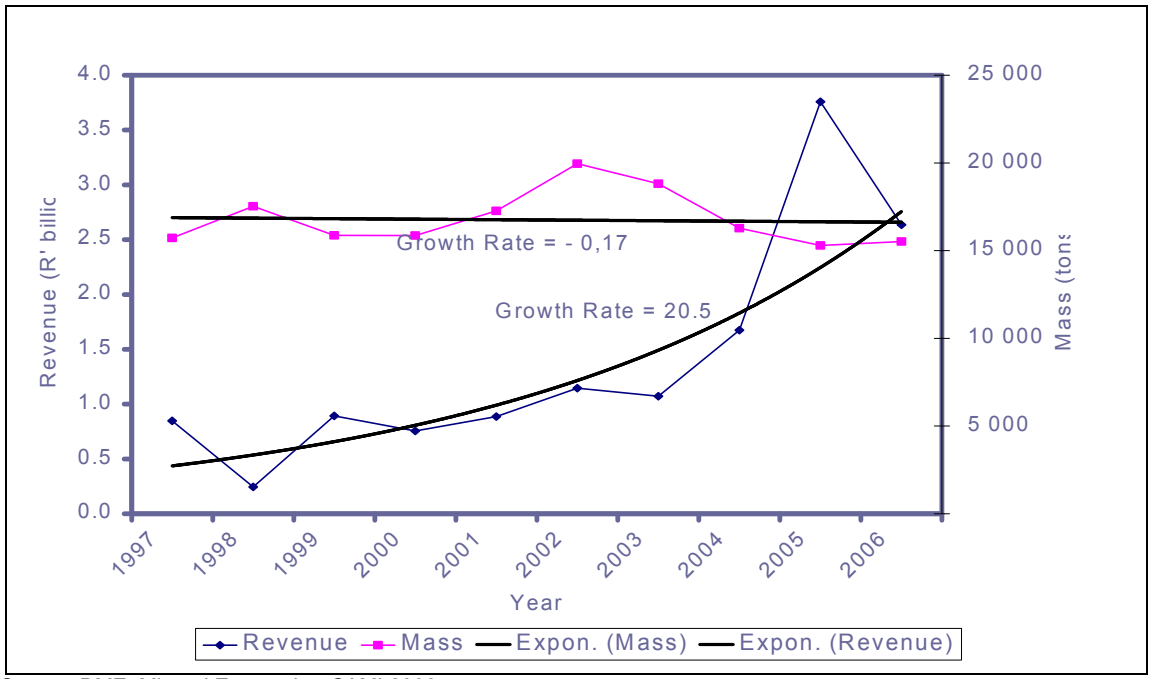
Source: DME, Mineral Economics, SAMI 2006.

SA unit values followed a similar trend to that of the prices. Local vanadium unit values have historically been higher than the export unit values, because the bulk of export material consists of slag which is low grade vanadium product. See export sales below.

- **Vanadium Export Sales**

Exports sales volumes declined at a rate of 0,17 per annum from 15,7 kt to 15,5 kt for the period under study. Revenue generated from exports increased by an average of 20,5 percent per annum from R484 million in 1997 to R2,6 billion in 2006 (Fig 8), as a result of higher prices and a weaker currency.

Figure 9: SA Vanadium Export Sales, 1997 – 2006

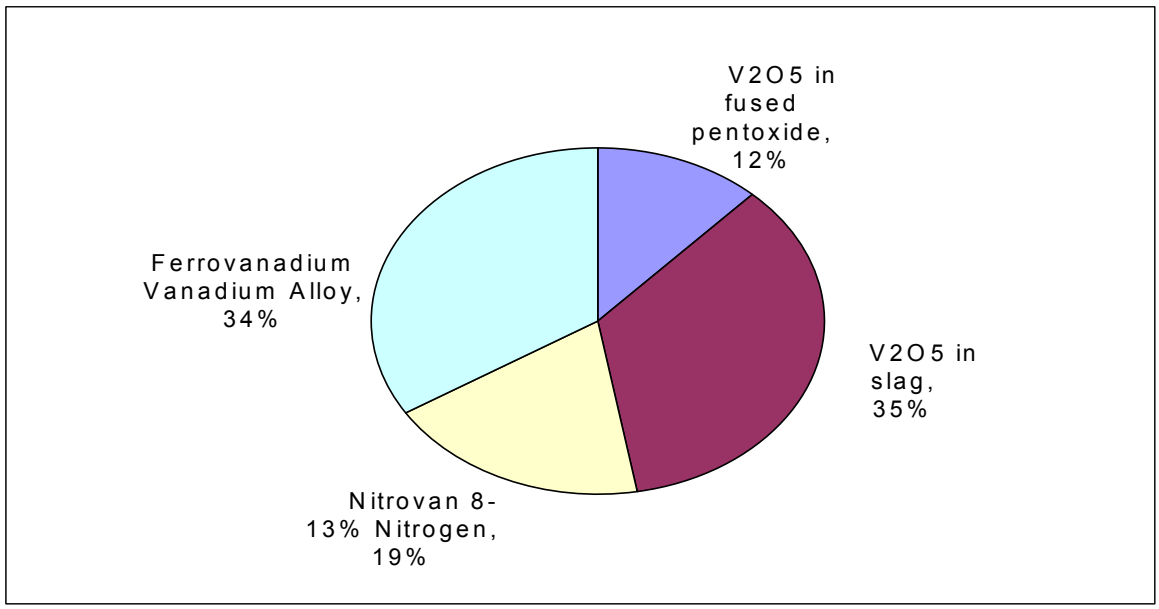


Source: DME, Mineral Economics, SAMI 2006.

- **Export Sales Distribution**

At 35 percent, V_2O_5 in slag constituted a large portion of vanadium exports volumes. Revenue generated from these volumes amounted to only 4 percent (Fig 10 and 11) of export sales, at a unit value of around R20 per ton.

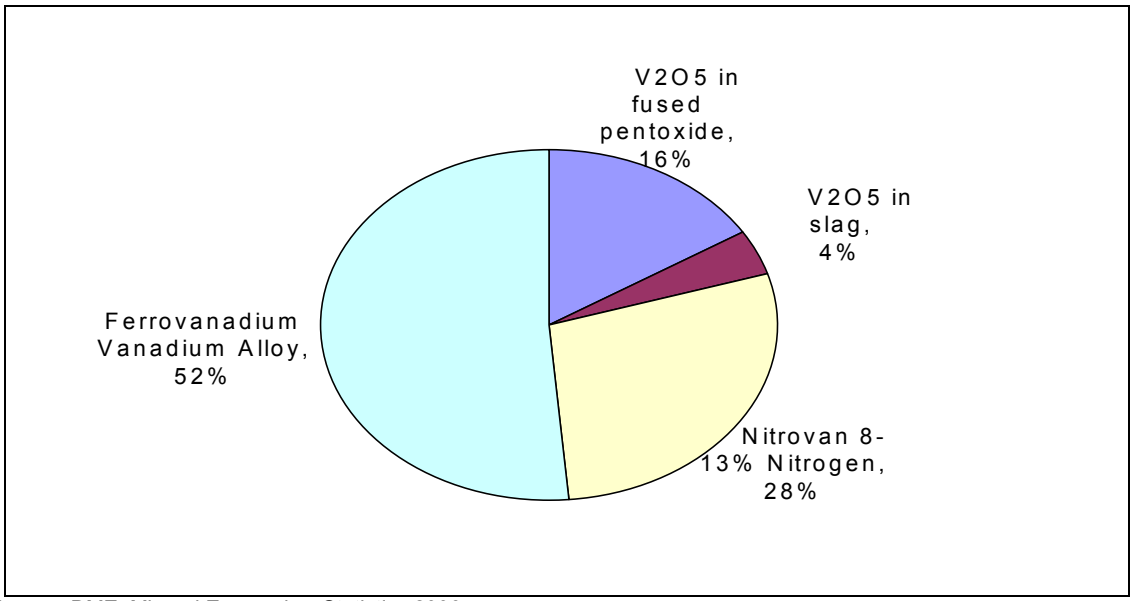
Figure 10: Export Mass Distribution, 2006



Source: DME, Mineral Economics, Statistics 2006.

The second largest export volumes are in a form of Ferrovanadium alloy, which accounts for 34 percent of the export revenue. The corresponding unit value was R257/t in 2006. Nitrovan and fused pentoxide accounted for 19 and 12 percent of export sales mass, generating 28 and 16 percent of export revenue at unit values of R249/t and R215/t, respectively.

Figure 11: Export Revenue Distribution, 2006

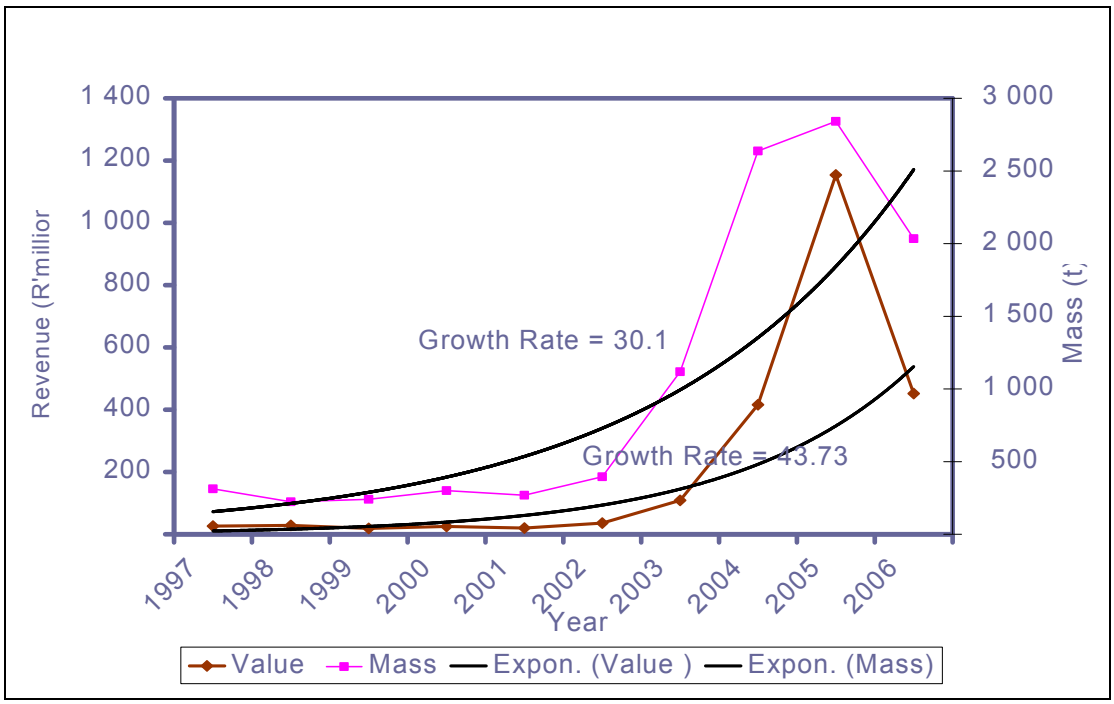


Source: DME, Mineral Economics, Statistics 2006.

- **Domestic Sales**

The domestic sales mass increased at a rate of 30,1 percent per annum from 313 t in 1997 to 2 034 t in 2006, while revenue from local sales grew by an average rate of 44 percent per annum from R26 million to R451 million (Fig 12). However, these sales remained steady at around 290 t from 1997 to 2002, as a result of unattractive prices, which led to steady revenues during the period.

Figure 12: Domestic Vanadium Sales, 1997 - 2006



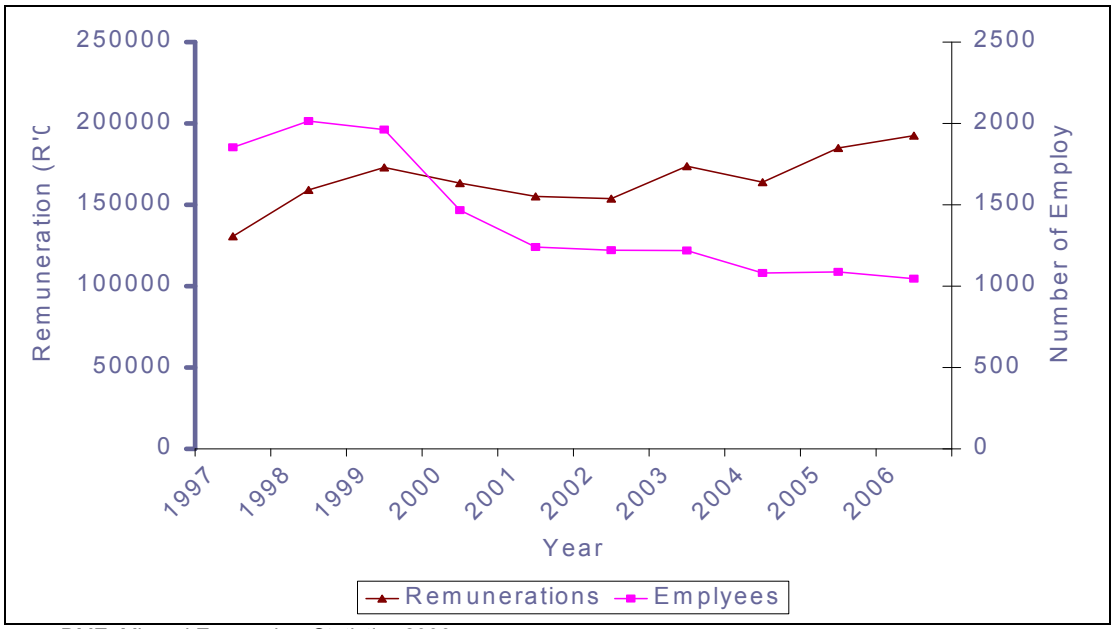
Source: DME, Mineral Economics, Statistics 2006.

Sales volumes increased by 183 percent from 395 t in 2002 to 1 119 t in 2003, on the back of attractive prices and higher demand from the international market, particularly China. As prices continued to rise steeply in 2004 and 2005, local sales also followed a similar trend. Consequently, revenues generated increased. In 2005, local sales volumes increased to 2 841 t, generating a revenue of R1,2 billion, as a result of the aforementioned reasons.

7. EMPLOYMENT IN SA VANADIUM INDUSTRY

The number of employees in the SA Vanadium Industry has declined at a rate of 7,9 percent per annum from 1 853 in 1997 to 1 046 in 2006 (Fig 13), this is attributed to the closure of Xstrata's Vantech operation and increased technology utilization. The corresponding remunerations increased at a rate of 2,7 percent from R131 million in 1997 to R193 million in 2006.

Figure 13: Employment in the SA Vanadium Industry, 1997 – 2006



Source: DME, Mineral Economics, Statistics 2006.

8. CONCLUSIONS AND OUTLOOK

The South African vanadium production has grown by more than 50 percent from 1997 to 2006. Increased utilisation of vanadium in high strength steel has pushed its demand upwards leading to higher prices and production. This trend is projected to continue for an extended period, on a global level, as emerging economies (China, India and others) continue to industrialise. Increasing intensity of use, coupled with increasing steel production, is expected to see vanadium consumption in steel production grow by at least 7 percent per annum from 2006 onwards[7].

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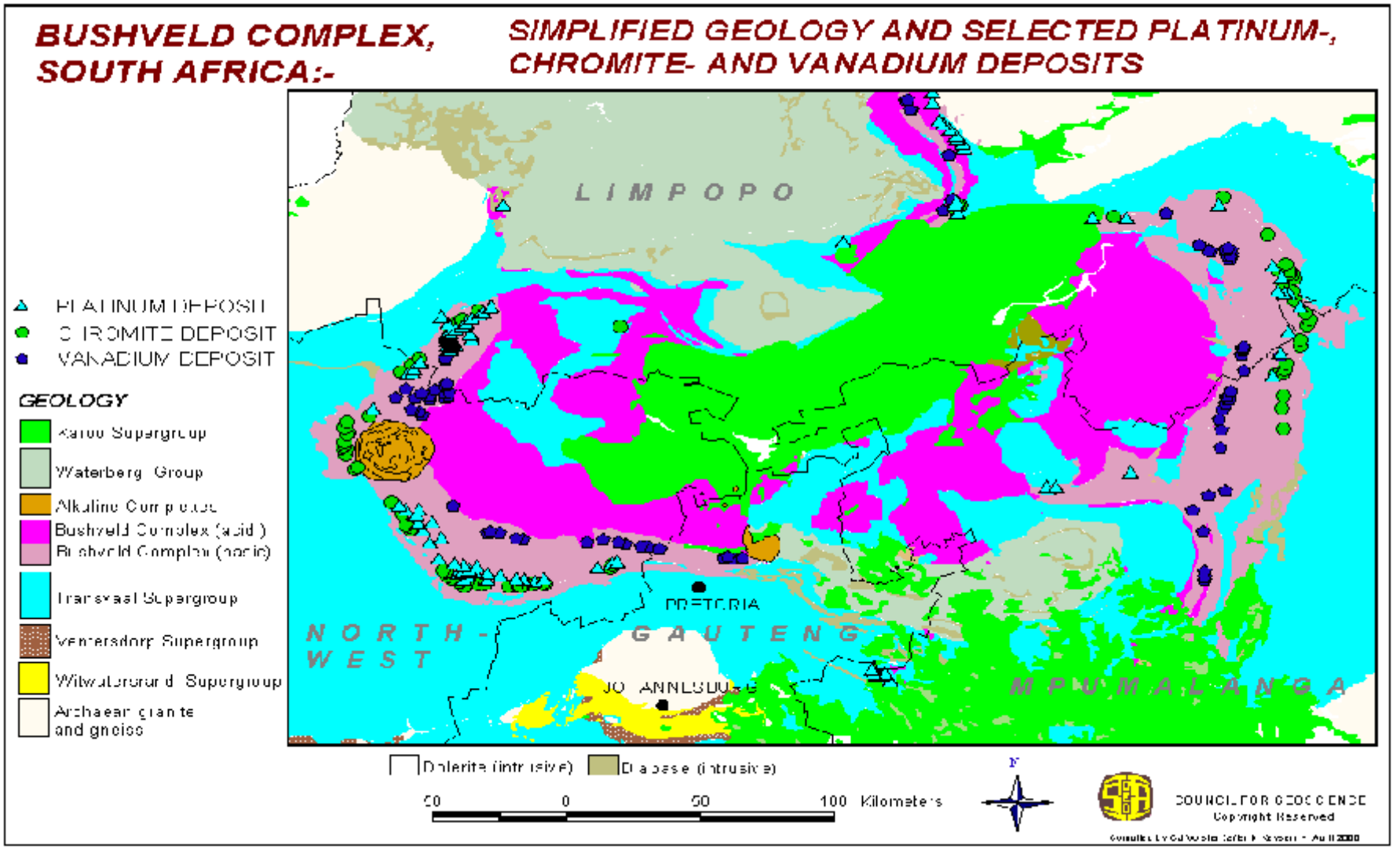
ANNEXURE 1

VANADIUM DEPOSITS ON THE BUSHFELD COMPLEX



ANNEXURE 2

VANADIUM EXTRACTION PROCESS