The Red Syenite of the Pilanesberg Complex as a nepheline source for the South African ceramics and glass industry.

By
Bukiwe Pantshi

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ABSTRACT

A viability study was undertaken on a farm Zandrivierspoort 210 JP, in the Pilanesberg Alkaline Complex to investigate the red syenite deposit. The red syenite deposit of interest is located in the south-western quadrant of the Pilanesberg. It is a potential source of nepheline, which is used as a flux in glass and ceramics industry. The study was aimed at establishing the demand for the material in South Africa and the market logistics related to its exploitation. Glass and ceramics manufacturers have different specifications as far as the quality and the product form is concerned. A market study conducted indicated that glass manufacturers require already beneficiated material with a low Fe content, depending on the kind of glass being manufactured. Ceramics manufactures also want material with low Fe content, but the material can be unbeneficiated as most of these factories already have facilities to remove Fe and other gangue. The common requirement is that material must be crushed and milled to a specific size. Red Syenite complies with the specifications of the ceramics manufacturer and did not comply directly with the specification of the glass manufacturer. The main reason for not non-compliance with glass specifications can be attributed to the fact that the material supplied was unbeneficiated. A major concern from the industry is the continuity of production from the deposit and an assurance of constant quality. It was also established that the availability of substitutes such as feldspar at a lower cost than nepheline results in an unwillingness of potential users to source nepheline despite its advantages. It is recommended that extensive geological studies be undertaken to confirm the resources and reserves of the entire nepheline-bearing deposits in the Pilanesberg. The mining of the deposit will be undertaken by employing a quarrying method, which will be followed by opencast to a depth of 50m. The Run-Of-Mine (ROM) will be crushed and milled to sizes specified by clients and the beneficiation process will follow. A financial investigation based on the known facts about the deposit established that capital, production rate, and selling price have the highest influence on the viability of the project. Transport and operating costs in this case showed a less significant influence on the viability of the project.

CHAPTER 1

1. INTRODUCTION

Nepheline syenite is a rare igneous rock that resembles granite in texture, except for the fact that it consists principally of nepheline and alkali feldspars. Nepheline is a major rock-forming mineral. More than 90% of the nepheline syenite mined worldwide is used in manufacturing glass, ceramics, paint, and filler material (Daly, 1990). Deposits worked at a larger scale are located in Canada, New Mexico, Norway, USSR and United States of America (USA). More than 60% of the global annual production is exported to USA and about 20% to Canada. There is only limited mining of nepheline syenite in South Africa. Instead, feldspar is used as a main source of alkalis and alumina in glass manufacturing (Boelema, 2000).

It is believed that there is a market for nepheline as it possesses some advantages over currently used raw materials such as feldspar. Nepheline syenite is exceedingly rich in alkalis and alumina, hence the abundance of Feldpathoids and alkali feldspars. In the glass industry, nepheline syenite is used as a source of Al_2O_3, Na_2O, and/or K_2O, SiO_2 in the manufacturing of various types of glass (soda-lime (flat and container) glass, fibreglass, borosilicate glass).

In glass and ceramics manufacturing, nepheline, like feldspar, provides alkalis that act as a flux to lower the melting temperature of a glass or ceramics mixture. This prompts fast melting and fuel savings (U.S.G.S Minerals Yearbook, 2003). In glass, nepheline supplies alumina, which gives improved thermal endurance, increased chemical durability and increased resistance to scratching and breaking. Silicate ceramics are based on clay plus nepheline or feldspar and other additives such as talc, carbonate, bone ash, wollastinonite, depending on the specifications of the product. This study is conducted to investigate the viability of the south-western portion of the Red Syenite of the Pilanesberg Complex.

The nepheline syenite rock is crushed, milled and subjected to a series of magnetic separators in order to reduce the iron content. The characteristics of the product are modified to meet the specifications of individual customers as far as particle size and iron level. The limiting factor in exploitation of nepheline syenite in South Africa is the iron content, percentage of dark minerals and the location of the deposit in terms of its market. The location of the deposit is an issue for all industrial minerals; being closer to Gauteng, which is the principal market, is most advantageous.

1.1. Statement of research question

Is the exploitation of the South-western portion of the Pilanesberg Red Syenite a financially viable project?

Sub-questions

a) What is the composition of the nepheline syenite of interest?
b) Is the Red Syenite a financially viable deposit considering quality, size and location in terms of market?
c) Is there an adequate demand for nepheline in South Africa?
d) Is the product suitable for industry's demand?
e) Are ceramics and glass manufacturers willing to change to nepheline?
f) What is the economic relationship between distance from source and market?
g) How sensitive is the operation to market conditions?
h) What is the most viable way of exploiting and selling the product?

1.2. The hypothesis

a) Red Syenite has the potential to be a viable producer of nepheline for both local and export markets.
b) Nepheline generally has advantages over feldspars used in glass and ceramics.
c) Glass and ceramics manufacturers do not commonly use nepheline because of its scarcity. Another reason the glass and ceramics manufacturers do not use commonly nepheline could be that they are using feldspar which is abundant. Large deposits of nepheline syenite that guarantee consistent supply are limited in South Africa. There is only one known nepheline supplier in Pretoria.
d) More detailed sampling of the Red Syenite deposit will define the compositional variation within the deposit.
e) Investigating the Red Syenite deposit using specifications required by South African users will address issues on its viability in the country, a comparison with Canadian or Norwegian products would have less value.

1.3. Assumptions

a) Establishing a mining operation will contribute to the development of the community. There will be creation of job opportunities.
b) Mining, processing and transport functions and management of the operation will be outsourced.
c) The demand for ceramics and glass in the building industry will lead to an increase
d) The market of interest is located in the Gauteng Province.

1.4. Purpose of the study

The study is conducted to verify the viability of the Red Syenite deposit as a supplier of nepheline in the South African glass and ceramics market. The company that is undertaking the study intends to exploit the deposit by quarrying. The company is also the holder of the old order prospecting right, which is in the process of conversion to the new order right as required by the Mineral and Petroleum Resources Development Act (2002) (MPRDA). The investigation entails the following issues:

a) The acceptability of the mineral product that could be mined and extracted from the Red Syenite deposit;
b) The availability of sufficient resources to supply both ceramics and glass manufacturers;
c) If the quality of the Red Syenite meets South African specifications especially in the glass and ceramics industry;
d) The potential demand for the product;
e) The technical feasibility of a mining and beneficiation operation based on the Red Syenite deposit, producing the required mineral product in terms of quality and quantity;
f) The financial viability of exploiting the Red Syenite deposit; and
g) Identifying threats that could negatively affect the viability of the project.

1.5. Acknowledgements

I would like to thank Randgold and Exploration Limited for giving me an opportunity to investigate The Bull's Run nepheline syenite deposit that eventually led to establishing Pilanesberg Red Syenite as my ultimate project. My thanks are specifically due to Mr Rob Lindsay, Technical Manager whom we took several trips to the Pilanesberg together and his encouragement.

Gratitude is sincerely expressed to my supervisor Professor Hennie Theart, Department of Geology at the University of Pretoria for his contribution and constructive criticism.

CHAPTER 2

2. REVIEW OF THE RELATED LITERATURE

The study area is located in the Pilanesberg Alkaline Complex (Pilanesberg), 50km north-north-west of Rustenburg, 10 km south-west of SunCity. The Pilanesberg Alkaline Complex is geologically situated in the western limb of the Bushveld complex, where a number of companies mine platinum group metals (Figure 1). The western limb extends 200 km along an arc from Thabazimbi to the north of Pretoria (Cawthorn, 2001). Pilanesberg is situated on the junction of the norite and the red granite of the Bushveld Complex. This is evident in the remnants of red granite along with Red Syenite that are found in some breccias (Shand, 1932).The Pilanesberg is almost perfectly circular with an east-west diameter of 28 km and north-south diameter of 24 km (Figure 2).

A number of companies have worked in the area in the past to mine syenite and foyaite material for dimension stone. The study area includes a syenite hill on the farm Zandrivierspoort 210 JP (Figure 3). Pilanesberg is well known for its nature reserves, the study area is located south of the boundary of the heritage site. However, a part of Zandrivierspoort 210 JP is included in the heritage park (Appendix D), this portion of the farm is north of the Sandspruit and does form part of the proposed mining area.

2.1. Geology of the Pilanesberg Alkaline Complex

In 1905, Molengraaff among other scientists who passed through the Pilanesberg Alkaline Complex recognised the nepheline-bearing rocks (Lurie, 1986). Brower, in 1910, studied the petrography of the rocks and was among the first to recognise the circular structure of the complex. Humphrey, in 1914, also noted that there were outcrops of sedimentary rocks at Mahobieskraal 211 JP south of Pilanesberg and along the Bier Spruit.

Humphrey in 1914 classified the formations in the area as:

a) Transvaal System - Dolomite & Pretoria System
b) Waterberg System - Volcanic breccia
c) Bushveld Igneous Complex - Granite, norite & pyroxenite
d) Pilanesberg Alkaline Complex - Red syenite, foyaite & lujaurite and nepheline syenite
e) Volcanic rocks - Lava, breccia and tuffs

He roughly classified plutonic rocks into three groups, as indicated above, as these had the character of syenites.

Shand, between 1923 and 1924, did some field work, where he identified that the Pilanesberg is built of a base of intrusive rocks and a cover of volcanic rocks. The intrusive rocks consist of concentric rings of foyaite and syenite, whilst the volcanic cover comprises lavas, tuffs, and very coarse breccias (Shand, 1932).

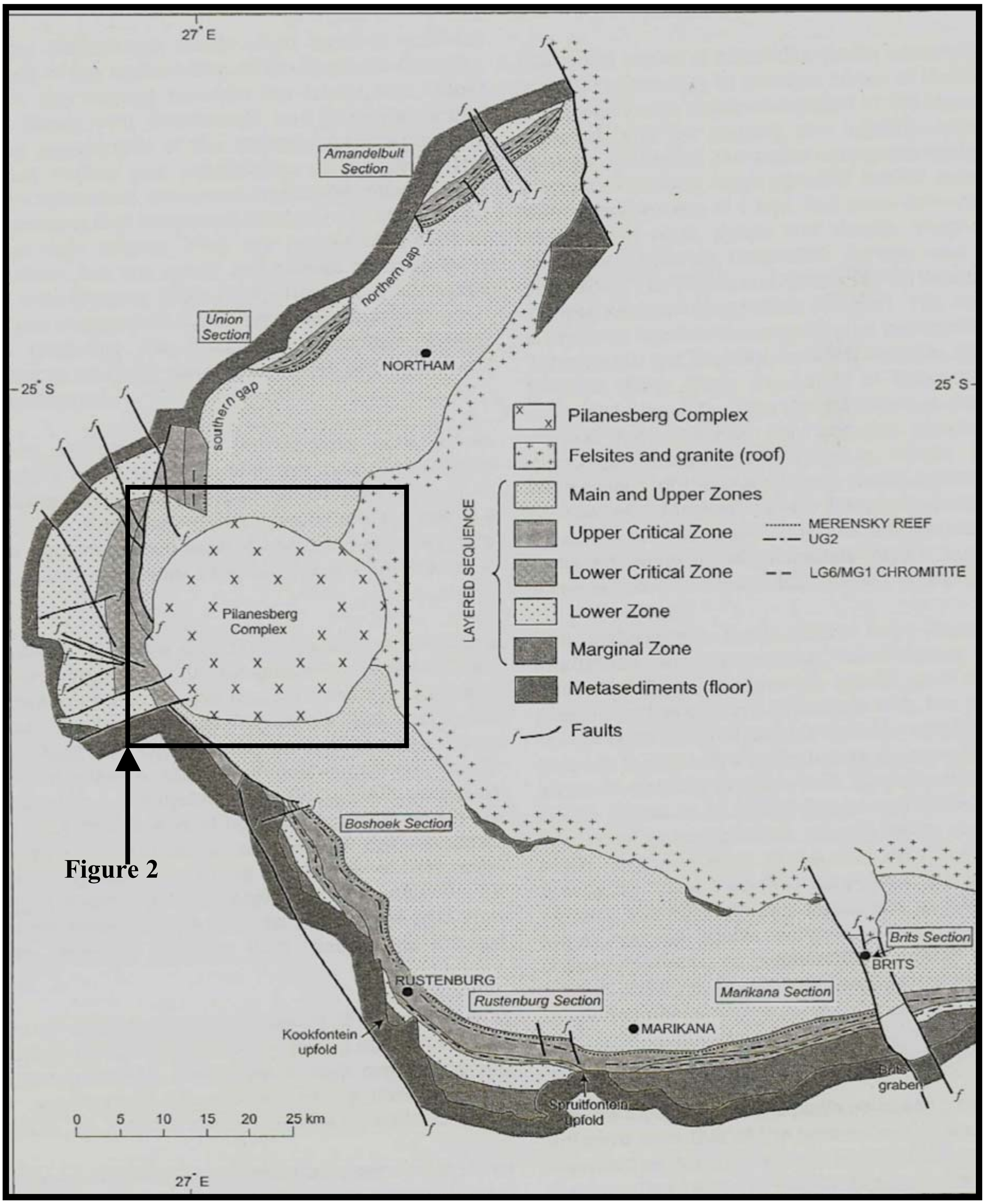

Figure 1: Location of the Pilanesberg Complex, also showing the geology of the western limb of the Bushveld Complex. (Viljoen, 1998).

He did a lot of comparison with previous findings of other geologists such as Brower and Humphrey. Decades of more investigations followed and Pilanesberg was not recognised as a likely source of economic minerals. Up to the 1980s, the main interest was in rare earth elements and exploration indicated a potential for niobium, uranium, rare-earth and thorium ore.

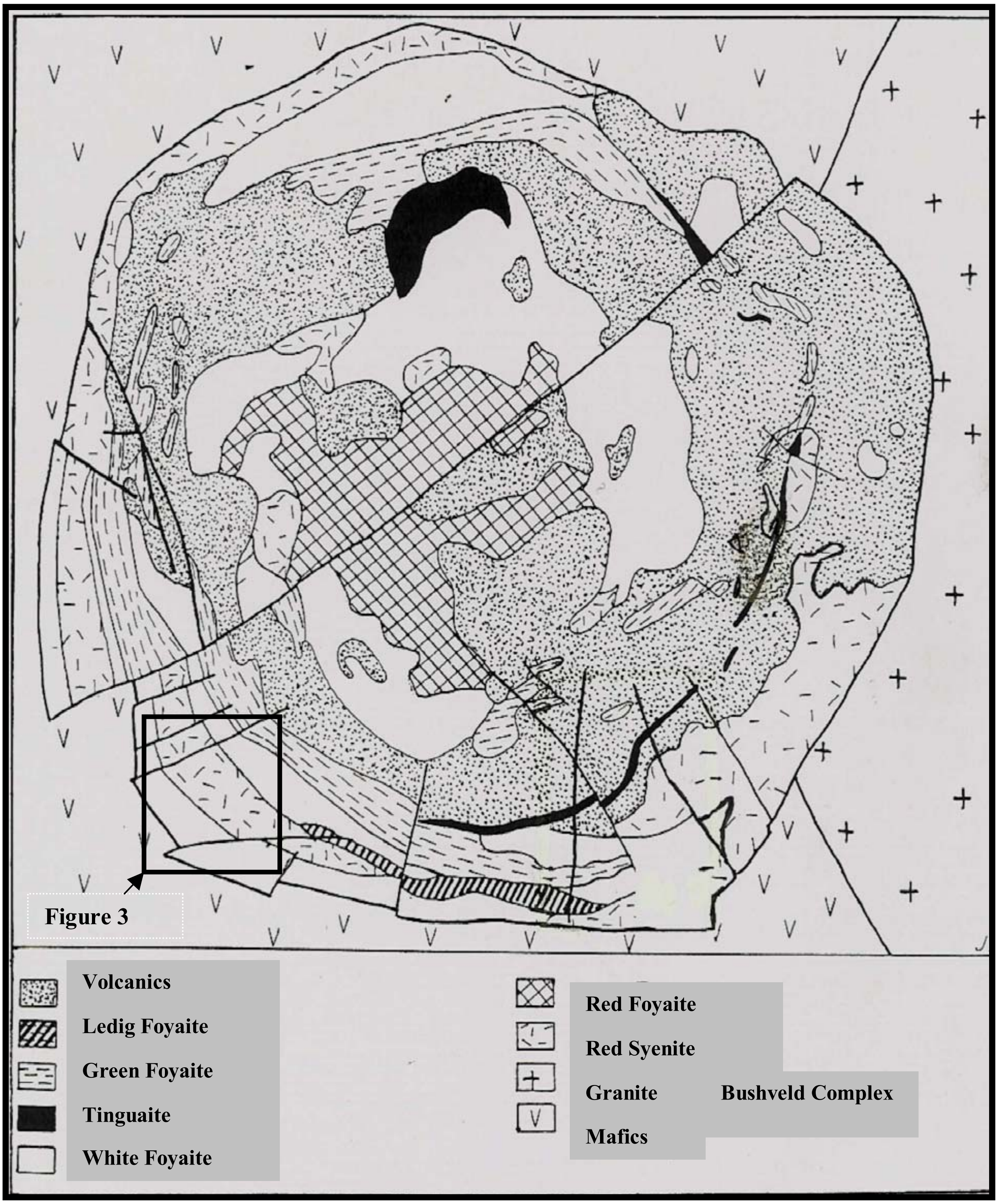

Figure 2: Geology of the Pilanesberg Complex (Lurie, 1986).

A summary of the lithological elements that resulted from Shand's 1932, Retief's 1968 and Lurie's 1986 studies are given in the paragraphs below (Appendix A):

2.1.1. Red Foyaite

The core of the Pilanesberg Complex is made up of coarse grained Red Foyaite also has two outlying lobes of Red Syenite. One body forms a red hill in the southern part of the farm

Buffelspan. The second body forms a big round hill in the eastern part of Welgeval, both south and north of the Rhenoster Spruit. Shand (1932), Shand estimated the Red Foyaite to cover an area of 6474.97 hectares. Red foyaite in the core of the structure is younger than the Red Foyaite and lava, and it has been observed to intrude into the lava (Lurie, 1986). The syenite is also observed to underlay the volcanic rocks in farms such as Buffelspan and further north in the complex.

The texture of Red Foyaite and its liebenerite content varies throughout the complex. The feldspar is mainly perthite and albite, while the dark minerals are mainly biotite, aegerine, and iron ore. The accessory minerals include fluorite and zircon, while the common decomposition product is chlorite. Lurie, 1986 established that the Red Foyaite has the lowest content of the rare earth elements

2.1.2. White and Grey Foyaite

The core of the complex is succeeded by a complete ring of white foyaite which is sometimes referred to as grey foyaite. The white foyaite surrounds the red foyaite core and has the largest outcrop of all the intrusives. The white foyaite is identified by its white or grey colour, which is due to the predominance of minerals such as feldspar (Lurie, 1986). Retief in 1968 conducted a petrographic study on white foyaite and identified six major types throughout the complex (Appendix B). The results of the study clearly indicate that the white foyaite varies in texture and mineralogy throughout the complex. Shand in 1932 also identified the variation in texture and mineralogy throughout the complex. There is also a green foyaite which lies between the white foyaite rings. In some areas the white foyaite is covered by volcanic rocks. It is, in some areas, enclosed between the red syenite and the tinguaite. The white foyaite forms the floor of the valley and part of the outer wall from Thirteenth Poort to Fifteenth Poort. It forms the outer wall of Pilanesberg on Palmietfontein, Zandrivierspoort and Koedesfontein, with minor developments of red syenite within. The ring structure of the white foyaite has an average width of 5 to 7.6m. (Lurie, 1986).

The white foyaite is non-porphyritic, but contains large feldspar crystals. Nepheline usually ranges from a third to half of the rock by volume. It mainly consists of soda-potash feldspar, nepheline and aegerine, with minor constituents of eudialyte and sodalite (Shand, 1932). Aegerine is the principal dark mineral in either slender needles or ophitic masses that enclose both feldspar and nepheline.

Some of the analysis of white foyaite gave the following chemical results (Shand, 1932):

	I	**II**
SiO_2	**49.88**	**55.50**
Al_2O_3	**21.70**	**19.87**
Fe_2O_3	**1.30**	**3.34**
FeO	**0.53**	**0.76**
MgO	**0.07**	**0.28**
CaO	**3.29**	**1.63**
Na_2O	**11.80**	**9.91**
K_2O	**4.66**	**5.41**
MnO		**0.60**
P_2O_5	**trace**	**absent**
Total	**93.23**	**97.3**

The white foyaite is observed to generally weather into large, rounded mass which has a tendency to split off a succession of concrentric shells. This characteristic is particularly observed in the Matooster type north of Mahobieskraal and Zandrivierspoort. The green foyaite which is found within the white foyaite differs slightly from the latter. However, there was a difficulty in distinguishing between the two microscopically, although the task was easy in the field.

2.1.3. Tinguaite

Tinguaite in the Pilanesberg can be found in 3 forms viz., as a half ring, a large sheet capping the Pilanesberg proper and as thin dykes mainly concentrated in the north-western sector of the Complex (Lurie, 1986). Tinguaite can be traced within the green foyaite between the farms Ledig and Kaffirskraal. Shand (1932) established that it represents a dyke-like zone, which is probably a maximum zone of compression within the green foyaite ring.

Tinguaite is porphyritic and green to grey in colour, consisting of k-feldspar, nepheline and minor aegerine-augite phenocrysts that are set in a fine-grained groundmass consisting mainly of pyroxene.

The relative age of tinguaite can be established from the observation at the contact zone between green foyaite and tinguaite. Inclusions of tinguaite in the foyaite have been observed. Inclusions of white foyaite and lava have also been observed within tinguaite dykes. From the observations, the age order is believed to be: lava, white foyaite, tinguaite, green foyaite (Lurie, 1986).

2.1.4. Green Foyaite

Green foyaite lies between second and third white foyaite rings (figure 2). It forms the sharp-crested hills on Vaalboschlaagte.This foyaite tends to be porphyritic in texture. Retief (1963), on the basis of texture classified the green foyaite into two categories, viz., the Green Foyaite and the Lujaurite & Microlujaurite. The main minerals in the green foyaite are microcline, pyroxene. Accessory and rare minerals include zeolites, sodalite, lamprophyllite, lovchorrite, zircon, sphene, calcite, fluorite, and magnetite. Lujaurite is a variety of nepheline syenite containing aegirine and eudialyte.

The green foyaite has been observed to vary in grain size from medium- to coarse-grained and even fine-grained in some localities. The fine-grained green foyaite is eminent in the northern sector on Koedesfontein and it has a close to tinguaite (Lurie, 1986).

2.1.5. Ledig Foyaite

Lurie (1986) made an observation that the Ledig Foyaite extends to the west of Zandrivierspoort and Koedesfontein boundary. The existence of this foyaite was also observed by Retief in 1968. Lurie made significant observations that differ from the study conducted by Retief, in which he identified some of the Ledig foyaite as white foyaite.

In his study, Retief identified two types viz., Types 1 and 2. In Type 1 nepheline is abundant and perthite is the major feldspar, whereas in Type 2 nepheline is absent and microcline is the main feldspar.

Lurie (1986) established that the Ledig Foyaite in overall has the highest content of rare earth elements.

2.1.6. Red Syenite

Last is a complete ring of red syenite which is prominent in the south-east and north-west, forming the outer wall of the Pilanesberg. On the farms Palmietfontein, Zandrivierspoort and Koedesfontein, the Red Syenite is developed within the white foyaite ring (Figure 2). In this area the red syenite deposit forms a prominent hill along the road and it is called Burgwan's Kop. The syenite appears to be very homogenous and has similar petrographic characteristics throughout the ring. The contact between the white foyaite and red syenite is believed to be gradational, as no sharp change was observed. But in some areas, dykes of foyaite cut the red syenite, making it clear that foyaite magma came in later than the syenite type.

Some of the analysis of the Red Syenite as reported by Shand (1932):

SiO_2	**57.77**
Al_2O_3	**18.08**
Fe_2O_3	**0.78**
FeO	**4.69**
MgO	**1.00**
CaO	**2.27**
Na_2O	**5.53**
K_2O	**5.26**
MnO	**0.22**
P_2O_5	**0.21**
Total	**95.81**

The syenite is characterised by tubular crystals of feldspar which vary in colour from pink to red with minor dark minerals. The feldspar is mainly perthite and albite, while dark minerals include biotite, aegirine and iron ore.

2.1.7. Volcanic rocks

Volcanic rocks such as lava, tuffs and breccias form part of the Pilanesberg Complex. These rocks were intruded by plutonic rocks throughout the structure. Greater masses of lava are found to the south-east of the farm Houwater, on Vaalboschlaagte, Schaapkraal plateau, and Nooitgedacht. The tuffs have been identified as dark-grey or occasionally pink, resembling slates and mudstones. They are also marked by an irregular stratification of alternating coarser and fine layers. A major development of breccias is found on the east side of Pilanesberg from Rhenosterspruit to Saulspoort. It is also developed outside the green foyaite ring. There is also volcanic agglomerate that occurs to the north side of the Kaffirskraal valley. It consists of rounded boulders of camptonite in a matrix of fine to medium fragments of similar material. It is, however, difficult to determine the relative age of the different intrusive phases and distinguish the contacts.

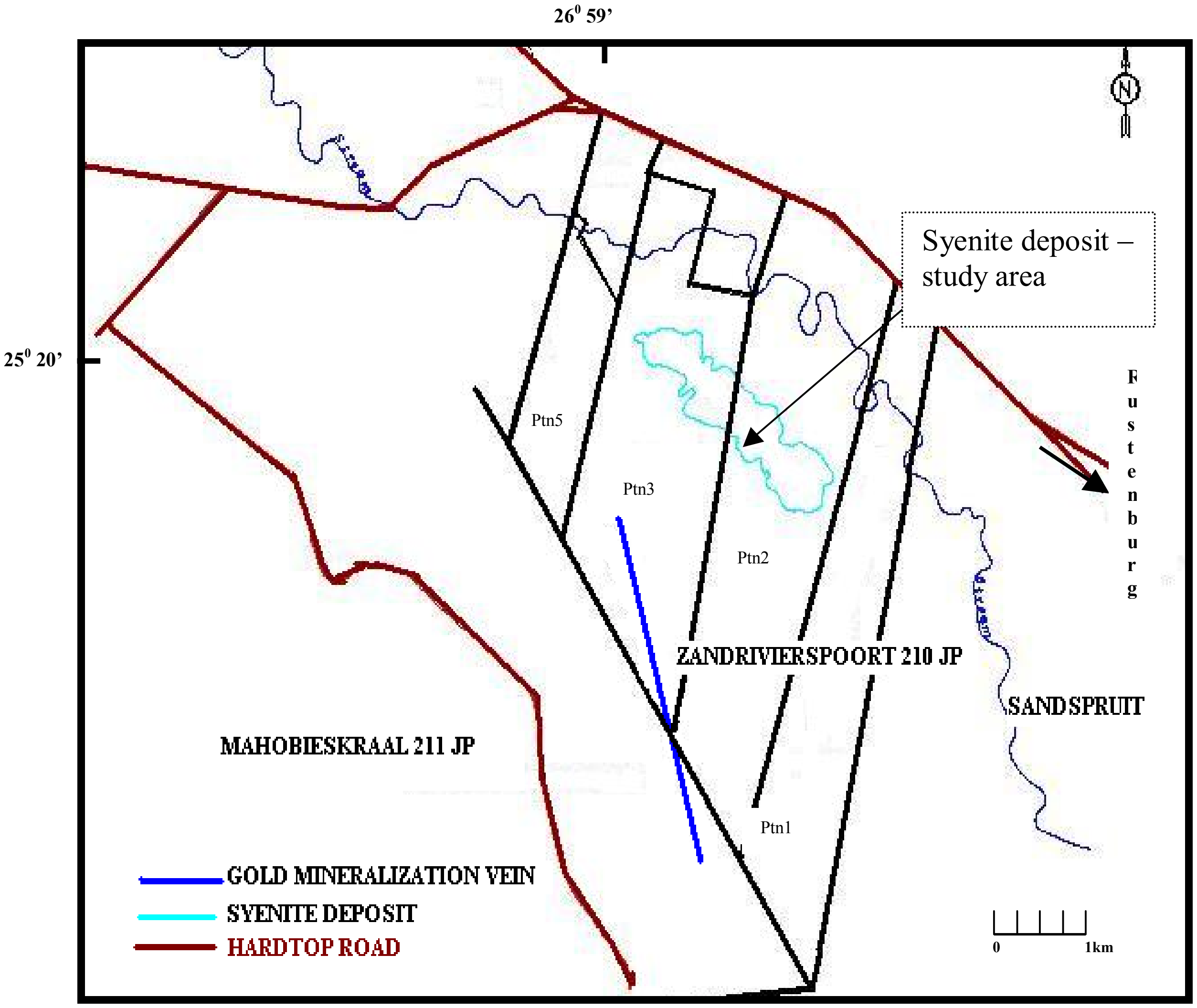

Figure 3: The location of the study area – Zandrivierspoort 210 JP – in relation to the main infrastructure

2.2. Age of the plutonic rocks

The Pilanesberg Complex has a poorly constrained age of 1250 ± 60 Ma (SACS, 1980). The complex is clearly younger than the Bushveld Complex, which it intrudes. The Rustenburg

Layered suite is well constrained at 2061 ± 0.8 Ma (Bogatikov, 2000) with granites of 2052 ± 48 Ma, which would imply that the Pilanesberg is younger than 2061 Ma, but still within age bracket 1190 Ma to 1258 Ma.

Both Humphrey (1914) and Shand (1932) in their investigations found that the volcanic rocks were older than the plutonic rocks, and sited the following observations:

2.2.1. Boulders of red granite embedded in the Red Syenite were observed at Rhenosterspruit. The granite was similar to the one mapped in the east and there was evidence that Red Syenite was of a younger age than the granite. Humphrey in 1914 observed that the Red Syenite was constantly traversed by a series of red felsitic dykes. Shand also observed fragments of red felsitic lava enclosed in the red syenite in the south part of Buffelspan and also fragments of pink tuff in the red syenite in Schaapkraal.

2.2.2. Red Syenite is traversed by foyaite dykes. However, the contact between the two is not sharp, making it difficult to determine the older rocks. Despite the difficulty, foyaite can be classified as the youngest of the plutonic rocks (Humphrey, 1914).

2.3. Mineral potential of the Pilanesberg

2.3.1. Gold

A company called Pilanesberg Gold Mine did an investigation of the gold potential of the area and located a small deposit which was initially mined by Zandrivierspoort Gold Mining Company Limited between 1935 and 1937. In 1982, Batemans and African Selection Trust undertook an exploration exercise for gold on Zandrivierspoort 210 JP and Mahobieskraal 211 JP. It was discovered that there is a NNW-SSE trending fault zone that separates the quartzites of the Pretoria Group and the Bushveld norites. This fault runs at a tangent to the Pilanesberg Alkaline Complex and it is terminated by an E-W trending fault related to the Zandrivierspoort gold occurrence. Lens-like quartz vein bodies are characteristic of the surface expression of the gold orebodies. Twenty-five boreholes were drilled to investigate the gold potential and it was found that there are two main orebodies along the mineralised fault zone, the north and the south body. These bodies are separated by a distance of approximately 600m. Gold mineralisation is not uniformly distributed. Arsenopyrite is the dominant sulphide in the quartz veins. It was established that the gold mineralisation is closely related to the emplacement of the quartz vein this is evident from boreholes that were drilled.

2.3.2. Rare Earth Elements

Zandrivierspoort was among properties that were investigated by Lurie (1973) for rare earth elements. The area underlain by Red Syenite was found to be highly radioactive, although foyaite is known to be the most reactive of all the major rock types. It was discovered that the

Pilanesberg as a whole is rich in zirconium, niobium, rare earth elements, thorium, uranium and strontium. However, these values did not reach the economic concentration to justify concentration. Green foyaite, red syenite and tuffs are some of the major rock types that show a significant sub-economic concentration of rare earth elements.

2.3.3. Dimension Stone

It is documented that a light greenish grey foyaite (syenite) which is commercially known as “Green Tweed and Palm Green” was quarried on the farms Zandrivierspoort 210 JP and neighbouring Palmietfontein 208 JP (Oosterhuis, 1998).

CHAPTER 3

3. GENERAL DISCUSSION OF NEPHELINE AND ASSOCIATED DEPOSITS

3.1. Characteristics of nepheline

Nepheline is the major rock forming mineral in nepheline syenite. It is white to grey in colour, and is distinguished from the feldspars, which it resembles, by its poorer cleavage and slightly greasy lustre. Table 2 below illustrates general characteristics of nepheline. It occurs as grains or large masses in many alkaline igneous rocks ranging from magnesium-rich nepheline basalts to granite-like, but quartz-free nepheline syenites. It is also found in some metamorphic rocks, particularly the nepheline gneisses of Ontario, Canada.

Table 1: Physical characteristics of nepheline (www.webmineral.com/).

Composition	(Na,K)AlSiO4
Colour	Off white to grey or brown
Lustre	Greasy to dull in weathered specimens
Transparency	Crystals are translucent
Crystal System	Hexagonal
Crystal Habits	Usually massive or granular
Cleavage	Poor, in three directions, prismatic, but rarely seen
Fracture	Conchoidal to uneven
Hardness	5.5 – 6
Specific Gravity	2.6+ (average)
Streak	White
Other Characteristics	Application of acids onto the surface of nepheline will cause a cloudy frosting. Powdered nepheline dissolves in hydrochloric acid.
Associated Minerals	Calcite, feldspars such as albite, apatite, biotite, hornblende, sodalite and other feldspathoids.
Major Deposits	Kola Peninsula, Russia; Mt. Vesuvius, Italy; Bancroft area, Ontario, Canada and Kennebec Co., Maine, USA.

Nepheline is also a principal component of several igneous rocks called nepheline monzonite and nephelinite. The basic difference between these is in the quantity and types of feldspars present. In nepheline syenite, potassium feldspars or K-spars are the predominant feldspar minerals. In nepheline monzonite rocks both K-spars and plagioclase feldspars are present in nearly equal proportions. In the nephelinites there are little or no feldspars present, and the rock is composed mostly of nepheline.

Nepheline is reactive with acids although it does not bubble like many of the carbonates. If powdered it will dissolve in hydrochloric acid, and if clear specimens are dipped in acid they will become cloudy or frosted. This could be helpful in distinguishing nepheline from some similar looking feldspars, scapolite and cryolite.

The greasy lustre of nepheline is also diagnostic. Massive nepheline with a greasy lustre is given the variety name “eleolite” which is derived from the Greek word for “oil”. “Nepheline” is derived from the Greek word for “cloud”, an allusion to its cloudy or translucent crystals and masses.

3.2. Classification of nepheline syenite orebodies

Nepheline syenite deposits are classified by the percentage of principal minerals present in the deposit, their colour, and by their origin (Minnes, 1975). A variety of names have been given to nepheline-bearing rocks, but the term “nepheline” is often given to any rock containing 5% or more of nepheline. However, a rock is only of commercial interest when the nepheline content is more than 20% (Minnes, 1975). Commercial nepheline syenite deposits and the products made from them are free of crystalline silica impurities (Cuillo and Robinson, 2003). These deposits are exploited for their high mineral brightness and low dark-mineral impurities. Commercial products are made by crushing, dry magnetic separation and milling. Fine-particle-size grading are produced by air classification.

In North America, typical nepheline syenite consists of approximately 25% nepheline, 55% sodium feldspar, and 20% potassium feldspar.

Syenites of Saudi Arabia’s Jabal Sawda Province, range in composition from alkali-feldspar to nepheline syenite. The main minerals are perthite (60-90%) and nepheline (0-40 %) with sodalite and very minor plagioclase, aegerine, ferro-hastingsite, augite, biotite and opaque minerals (http://www.sgs.org.sa/nepheline/).

Many types of nepheline syenites have been named after their localities; Laurdalite comes from Laurdal in Norway, Litchfieldite, another well-known type of nepheline syenite in which albite is a dominant feldspar, named after Litchfield in Maine, USA. Biotite, cancrinite and sodalite, as indicated in Table 1, are characteristic of this rock. Similarly, urtite is from Lujaur Urt on the White Sea and it consists mainly of nepheline, with aegerine and apatite, but no feldspar.
Some of the common terminology used for nepheline syenite rocks is defined in table 2.

3.3. Distribution of nepheline syenite deposits

Nepheline-bearing rocks, although relatively rare are widespread throughout the world and deposits of nepheline syenite are common amongst these. Larger syenite intrusions are known to exist in the United States (Texas, Arkansas and Massachusetts), Canada (Ontario, British Columbia), Brazil, Norway and the Russian Federation. There is only one occurrence in Great Britain. France and Portugal are also known to have a few deposits. They are also found in Bohemia and in several places in Sweden and Finland. South Africa, Madagascar, India, Mozambique, Tasmania (http://www.sgs.org.sa/nepheline/). Size is an important criterion for commercial considerations; more important are the purity and location of the deposit.

Table 2: Various nepheline syenite rocks (Minnes, 1975).

NEPHELINE SYENITE ROCKS	MINERALS
Congressite	**Mostly nepheline with minor orthoclase and albite.**
Craigmontite	**Nepheline predominates, oligoclase and minor corundum.**
Ditroite	**Nepheline, microcline, biotite, aegerine and soda amphibole.**
Fenite	**Nepheline, 70 – 90% perthite and 5 – 25% aegerine.**
Foyaite	**Nepheline, orthoclase, biotite, hornblende and augite-aegerine.**
Ijolite	**50 – 70% nepheline and aegerine.**
Laurdalite	**Nepheline, cryptoperthite, pyroxene, biotite and hornblende.**
Litchfieldite	**Nepheline, albite, orthoclase, cancrinite, albite.**
Melteigite	**Aegerine and less than 50% nepheline.**
Miascite	**Nepheline, microperthite, biotite and minor oligoclase.**
Monmouthite	**Nepheline, haustingsite and minor oligoclase.**
Ranglanite	**Nepheline with predominant oligoclase and minor corundum.**
Rouvillite	**Nepheline, gabbro-nepheline, hornblende, augite and labradorite.**
Urtite	**More than 70% nepheline and aegerine.**

Canada and Norway are principal producers of glass and ceramics. In South Africa, there are few companies that use nepheline from nepheline syenite to manufacture glass and ceramics. According to a documented information, South African deposits are located in KwaZulu-Natal (Bulls Run), Northwest (Pilanesberg) and Gauteng (Franspoort Syenite Intrusion). Their locations are a limiting factor in their commercial viability, hence the existence of only one operating the nepheline syenite quarry outside Pretoria.

Table 3 below shows a comparison of the processed composition of the Bulls Run nepheline syenite and some international examples.

Table 3: Chemical compositions of processed nepheline syenite (Pires, 2003)

ELEMENTS %	SOUTH AFRICA (Bulls Run)	CANADA	NORWAY	USSR
Al_2O_3	22.40	23.50	24.50	24
SiO_2	54.60	60.00	58.00	40
Fe_2O_3	0.51	0.09	0.09	2.86
Na_2O	7.64	10.40	8.00	10.65
MgO	0.38	-	-	-
K_2O	7.83	5.04	8.50	5.25
CaO	2.83	0.30	1.55	6
L.O.I.	2.45	0.50	-	-

3.3.1. Two deposits described for benchmarking

3.3.1.1. Table Mountain Deposit

The deposit is located at Table Mountain, Lincoln County, Oregon, Canada. Table Mountain is a plateau 822.96m above sea level, in the Siuislaw National Forest.

Table Mountain comprise of a deposit that is estimated to contain 26 million tons of measured resources of recoverable nepheline syenite, out of a total indicated resource of 525 million tons. In terms of Canadian standards, measured resources is defined as instances where grade and quality are known, and the quantity is computed from specific geologic evidence and dimensions revealed in outcrops, trenches, workings, or drill holes. Indicated resources is defined as instances where quantity is computed from information on grade and quality similar to that used for measured resources, with an assumed continuity between points of observation.

The Table Mountain nepheline syenite has a Mohs scale hardness of 6, a specific gravity of 2.57. U. S. Geological Survey Professional Paper 840 and the State of Oregon Department of Geology & Mineral Industries Bulletin 81 shows that the unprocessed material from Table Mountain contains:

SiO_2	**59.62%**
Al_2O_3	**18.60%**
Fe_2O_3	**2.86%**

The composition of commercially processed Grade A nepheline syenite is:

SiO_2	**60.04%**
Al_2O_3	**23.06%**
Fe_2O_3	**00.08%**

The high iron content of this material is seen as a limiting factor in utilising the Table Mountain material in the production of clear glass and ceramic items. This iron content is similar to the South African product. The discoloration caused by the iron is not an issue in beer and wine bottles. And high iron content has been shown to be desirable in roofing granules in that the impurity filters UV rays. Mill tests have shown that the removal of iron is feasible. Besides the iron content, other factors limiting the utilisation of the Table Mountain material in products such as rock wool, alumina, and extenders, is the location and the initial cost of developing the mine.

The total cost to process the raw nepheline syenite into commercial grades is estimated to range between $200 and $300 per ton. An estimated figure for the further processing of glass grade has been estimated at an additional cost of no more than $10 per ton.

The main competitor in North America - the Blue Mountain, Ontario deposit owned by Indusmin Ltd. This mine operates on raw material that contains 2% Fe_2O_3. After processing, the iron rich waste is sold as a 56% Fe by product.

3.3.1.2. Bulls Run Syenite Complex

This complex is located in the Natal Thrust Belt, 180 km east northeast of Durban (Scogings and Forster,1989). It is bounded in the south by Halambu Granitoid Gneiss and by Woshane amphibolites in the north (Germiquet, 1986). From north to south, the complex shows extensive plastic deformation. This zone is succeeded by a zone of fine grained nepheline syenite, which has been identified to be rich in biotite and muscovite (Scogings, 1992). The texture of nepheline syenite changes gradually towards the centre of the complex. It was identified that from the north nepheline syenite is fine grained and rich in both muscovite and biotite. Muscovite-microcline pegmatites and minor sulphides have been identified in the area. Results of some of the analysis done in the complex can be seen in Tables 3 and 6.

Samples collected from this deposit were sent for beneficiation trials to the same service provider used for Pilanesberg material reported in the current study. The material met the glass and ceramics grade specifications, although with a much lower yield in glass (Germiquet, 1986).

Samples were submitted to several glass and ceramics manufacturers. There was positive response from the companies who stated that the material was suitable for their manufacturing processes. However, it was stated that the companies could only consider using the material if its price was competitive to that of feldspar, which it could then replace. An exploration programme was conducted to identify the area with highest potential.

A cost study was also conducted. Although the financial parameters were positive, they were lower than what was normally desired for a new mining project at that time (Germiquet, 1986).

3.4. Evaluation of the raw material required in ceramics and glass

A range of raw materials can be used in ceramics and glass manufacturing, often interchangeably. The choice of raw material is dependent on the following considerations:

a) Cost per ton;

b) Chemical consistency of material;
c) Uniformity and consistency of grain size;
d) Total iron content;
e) Levels of other impurities;
f) Stability and sustainability of supply.

In glass manufacturing, raw materials used depend on the type of glass, cost per unit alumina, and percentage of alumina. Ceramics manufacturers source the raw material based on the type of ceramic product, cost per unit alkali, percentage of alumina, percentage of total alkalis, K:Na ratio, percentage of free silica, and colour on firing. All industries have their specifications regarding the Fe_2O_3, Al_2O_3 and SiO_2 contents. The following are some of the specifications for different products:

Glass: Minimum - Fe_2O_3 - 0.1 % Flint glass
Al_2O_3 - 23 %
Fe_2O_3 - 0.35 % Amber glass & fibre glass

Ceramics: Maximum - Fe_2O_3 - 0.07 %

3.4.1. General testing and evaluation requirements

When the intention is to mine a nepheline syenite deposit, the most important requirement is to characterize the nepheline syenite, by determining internal variations which are best studied using petrographic properties. To establish the market that the material is suitable for, selected samples are subjected to laboratory-scale processing that attempts to reproduce techniques that would be used in an operating plant for either glass or ceramic manufacturing or even extenders.

Prior to beneficiation, samples are crushed and inspected microscopically so as to establish the size at which total liberation occurs.

3.4.2. General beneficiation testwork

The objective of beneficiation testwork is to reduce the Fe content which can be done using the permanent roll magnet. This process is undertaken to upgrade the product by either wet or dry magnetic separation. Generally samples are crushed to less than 1.7mm and a representative aliquot of the crushed material is pulverised and sent for analyses for Fe_2O_3, Al_2O_3, Na_2O, K_2O, SiO_2 and MgO among other elements. Each of the crushed samples is processed wet on the permroll using a strong rare earth (Nd) magnet. Three fractions are collected; namely, magnetics, middlings and non-magnetics. Some of the companies use a dry magnetic separator, where each crushed sample is processed dry using a strong rare earth magnet. Alternative wet magnetic separation method is where nepheline syenite is upgraded on a wet batch solenoid magnetic separator (WHIMS).

The flow sheet that was used for the testwork conducted at Mintek on the Bulls Run material is given in figure 4.

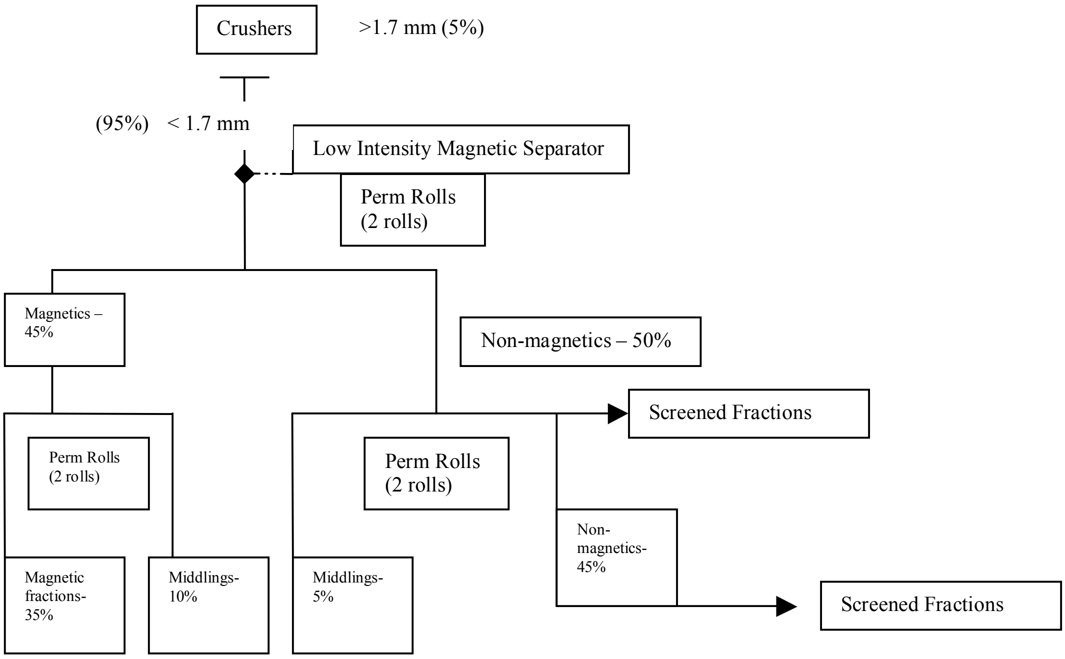

Figure 4: Beneficiation process of nepheline syenite (Germiquet, 1986).

3.4.3. Test for ceramics application

The fluxing character of nepheline is important in the production of ceramics. Most companies do a direct substitution of the material in their current body mix. Various tests are conducted and they include the following:

a) Standard Cone Fusion Test – to establish the fusion characteristics of the samples. This test is a function of particle size, particle size distribution, and chemical composition of the raw material.
b) pH Test – this provides an indication of the presence and solubility of impurities.
c) Other tests to evaluate the usefulness of the product include:
    a. Extraction characteristics;
    b. Body separation;
    c. Dry properties – shrinkage;
    d. Fired properties – shrinkage.

Dry brightness, refractory index, soil absorption, grain size distribution, pH and chemical composition of the raw material is crucial for other uses that include filler applications and extender pigment.

3.4.4. Test for glass application

The fusion method was used for this exercise by a glass manufacturer. A small fraction of nepheline is substituted for feldspar, melted, and the colour and appearance are compared with those of a regular glass melt. The advantage of this test is that the effects of impurities not previously detected will be apparent.

CHAPTER 4

4. THE CURRENT INVESTIGATION

4.1. Market study

The study was undertaken to investigate the feasibility of the deposits in South Africa, using data acquired from previous studies. Chemical analysis and metallurgical tests were done on a number of samples for this investigation in June 2004. Selected manufacturers were requested to test the Pilanesberg Red Syenite raw material in their plants. The objective of the exercise was to ascertain if it is worth doing an in-depth study of the Pilanesberg deposit. Previously, the results were compared with Norwegian specifications and those of a South African supplier, but the objective of this study is to use South African specifications for the financial model, hence, the focus is on the local market.

4.2. Exploration programme

For a comprehensive assessment of the current project area it is believed that a systematic sampling exercise is required to determine the homogeneity of the Red Syenite. This will also allow estimation of resources so as to address the issue of long-term supply. Obtaining representative samples that accurately characterise the deposit can be extremely difficult; and the careful design of the sampling programme would be crucial for the success of the project. Exploitation of an industrial mineral requires accurate information on the physical and chemical characteristics of the ore and final products.

The known surface area of the deposit is 7.8 hectares. A preliminary grid was designed at a line spacing of 50m and a sample spacing of 50m. Not all intended sample positions could be sampled due to terrain difficulties. Thirty samples were collected (Figure 6). Samples representing a particular area were mixed and a representative composite was submitted for analysis to a reputable service company. A petrographic study was conducted on representative samples to assess the petrographic variation of the deposit. Chemical analysis of the elements required by the ceramics and glass manufacturers conducted on representative samples.

A detailed radiometric survey may be considered in future as the potassium channel may indicate the presence and distribution of compositional zones.

4.3. Data analysis

Fifteen samples were submitted to a reputable service provider for x-ray fluorescence (XRF) analysis. The following major oxides were determined: SiO_2, Al_2O_3, Fe_2O_3, Na_2O, K_2O, CaO, BaO, SrO. In addition F, total Cl, and water soluble Cl and loss of ignition (L.O.I) were determined.

CHAPTER 5

5. DISCUSSION OF RESULTS

Results obtained from the study were compared with data from previous studies. Specifications from selected glass and ceramics manufacturers were used to test the compliance of this material. The aspects addressed are the following:

1. The composition of the deposit. This will be compared with specifications from both ceramics and glass manufacturers;
2. Demand of nepheline;
3. The demand-supply trend in South Africa;
4. An analysis of the results of the market study;
5. An analysis of the effect of beneficiation on the price/ton as compared to selling raw and beneficiated material; and
6. An analysis of the location of the deposit to the market and the transport costs.

5.1. Local market conditions

5.1.1. Ceramics market

5.1.1.1. Mamelodi Quarries Deposit

Over the past few years, relatively small quantities of nepheline have been produced from a small deposit called Mamelodi Quarries, near Pretoria. The product is locally used for glazing and ceramics. The nepheline syenite from this quarry is of low quality and is sold to customers who are not that stringent about the Fe content. It is either sold beneficiated (R800/t) or non-beneficiated (R400). Figure 5 below shows sales of nepheline (nepheline syenite) in South Africa between 1986 and 1998.

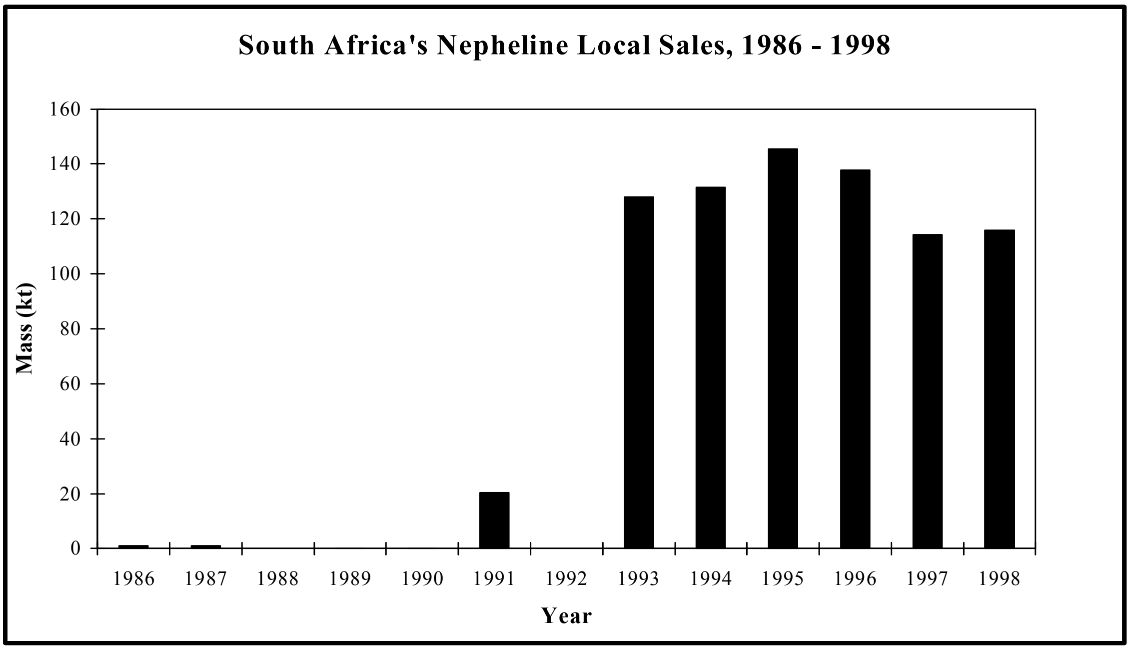

Figure 5: Documented sales of nepheline in South Africa (Agnello et al., 2003)

5.1.2. Glass market

It has been established that there is no supplier of glass grade nepheline in the country. There is also no producer willing to import this product South African manufacturers expect to pay below R150/kg for the delivered product (Pires, 2003).

5.1.3. Local market investigation

Unbeneficiated nepheline syenite rock samples from the current project were submitted to two companies that cannot be identified for confidentiality reasons, company A and company B. These companies tested the Red Syenite in their plants. Company A is a ceramic tiles manufacturer and B is a glass manufacturer. Other companies that were approached with a request for testing the material declined, by stating that they do not intend using nepheline because of its scarcity and the perceived expenses attached to acquiring it.

Company A, after testing the raw nepheline syenite in its system, showed interest in the material (Appendix C). Two of their three plants are using nepheline syenite in their ceramics manufacturing. The material was deemed suitable for their use, and was actually similar to the material they are currently sourcing.

Company B, reported that the material was not suitable for the glass they manufacture. The problem seemed to be a too high iron (Fe) content in the raw material. Company B was also not willing to explore the option of beneficiating the material.

From communicating with several other potential users, it was clear that most companies are not willing to substitute the raw material what they are using with nepheline syenite despite its advantages. There was also a general concern raised by potential users about the consistency in quality and supply, and the transport costs. Out of nine companies, only one in Gauteng is using nepheline syenite and is keen to sign a 5 to 10 year contract for a stockpile, if the material successfully test in the production trial as mentioned above.

5.2. International market

In 2004, nepheline production was mainly from Canada and Norway; there was no production from the United States of America (USA). This is believed to have led to an increase in global imports by 14%. Table 4 below shows the world production of nepheline.

Prior to 2004, 60% of the global nepheline production was exported to the United States of America, 20% to the Canadian market, and the remainder to other countries. In North America about 80% of feldspar and nepheline is used in glass manufacturing, about 15% in ceramics manufacturing and less than 5% in fillers. Growth in consumption of nepheline in glass containers has been affected by competition from metals and plastic containers (Potter, 1998). The use of nepheline in bathroom fixtures, tiles and fiber glass insulation depends on the housing construction and remodelling markets.

Canada and Norway produce nepheline mainly for glass and ceramic use. In Russia, it is mainly for the production of alumina, sodium, and potassium carbonates.

Table 4 : World production of nepheline in 2004 (Potter, 2004).

COUNTRY	PRODUCTION (tons)	EXPORT (tons)	LEADING RECIPIENTS
CANADA	**710 000**	**476 000**	**US - 350 000 t**
			Italy – 54 000 t
			Netherlands – 39 000 t
			Spain – 20 000 t
NORWAY	**340 000**	**336 000**	**Poland – 65 000 t**
			Germany – 58 000 t
			UK – 55 000 t
			Netherlands – 38 000 t
			France – 32 000 t
			Spain – 24 000 t

Table 5 gives a summary of the consumption of nepheline in the USA, and its value (Potter, 2004).

Table 5 : Consumption of nepheline in United States of America (Potter, 2004).

CONSUMPTION	2000	2001	2002	2003	2004
Quantity (tons)	**356 000**	**336 000**	**333 000**	**308 000**	**350 000**
Value ($000)	**24 800**	**24 100**	**26 100**	**28 200**	**29 000**

5.3. Petrography and chemical composition of the Red Syenite

From a total of thirty samples collected, fifteen were submitted for analysis (See figure 6). Table 6 shows the average composition obtained for the Red Syenite. As can be seen from the Table 6, the iron content of the raw material, which is a major concern in glass and ceramics manufacturing, varies between 4.80 and 5.70% and is represented by a mean of 5.43% in Table 6. The relatively high iron content is typical of South African deposits. The Bulls Run syenite was extensively sampled and the iron content varies between 4 and 8%. The samples analysed by Shand in 1923 of the Red Syenite has a similar iron content results as can be seen in section 2.1.6. Through processing the iron content of the Red Syenite can be reduced to an average of 0.81%. The alumina content of the unbeneficiated Red Syenite can be upgraded during beneficiation to over 20%. However, more work still needs to be done to determine possible minimum levels of iron content that can be obtained.

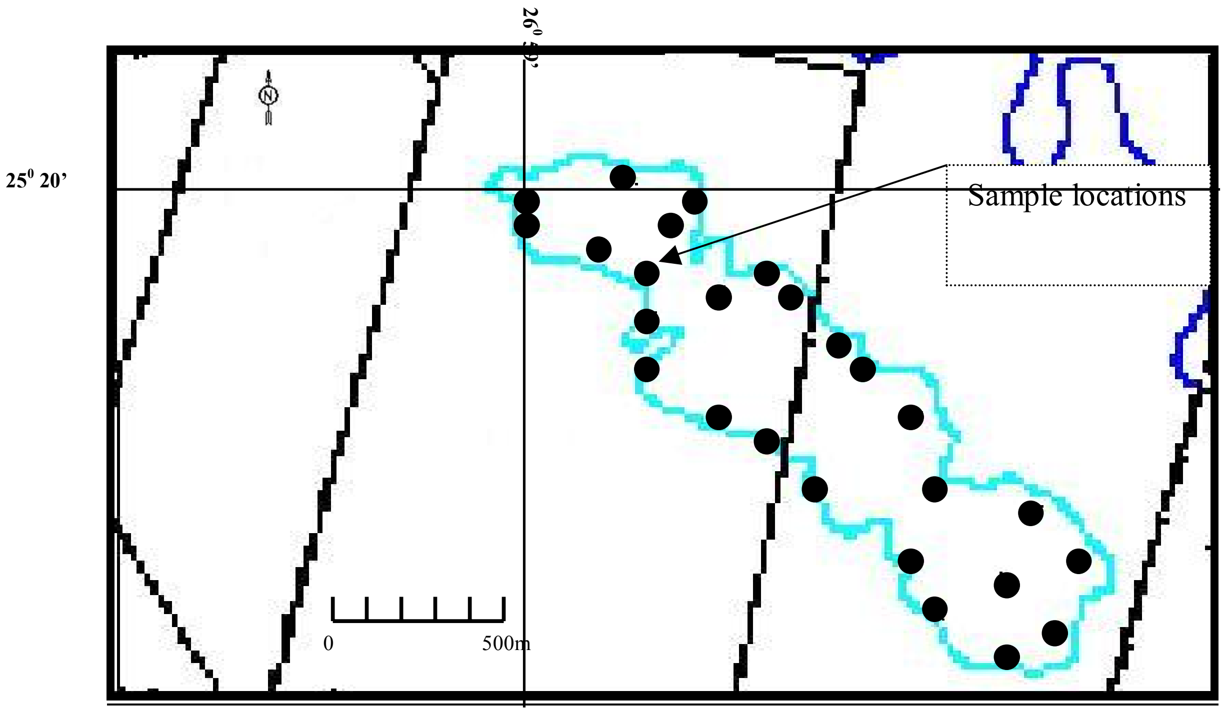

Figure 6: Sample locations in the Red Syenite deposit in Zandrivierspoort 210 JP

As indicated in the section 3.4, it was noted that various users have various specifications. Upgrade of material during beneficiation is done to obtain these specifications. In the case of Company A, unbeneficiated material is required. The company has a facility that removes iron and other elements that are not required. The material supplied has an affect on the price charged, as the unbeneficiated product is cheaper at an average of R450/ton, whereas the beneficiated product can earn up to R800/ton.

When comparing the composition of the Pilanesberg material to other countries, Red Syenite is of the same quality, in terms of the percentage nepheline (Table 8). This indicates that the material complies with specifications of certain glass and ceramic manufacturers. Reasons other than quality overshadow its chances of being a preferred raw material for these companies. In Table 8, types of dark minerals obtained in other nepheline syenite deposits in Canada and Norway are indicated (Minnes, 1975).

Table 6: Individual samples and statistics

SAMPLE	SG	SiO2	Al2O3	Fe2O3	MgO	CaO	MnO	P2O5	K2O	Na2O	Chloride	Total S	LOI
		%	%	%	%	%	%	%	%	%	%	%	%
001	2.67	58.2	14.9	4.95	0.71	1.24	0.28	1123 ppm	5.11	7.53	1547 ppm		1.16
002	2.66	59.3	15.1	5.24	0.71	1.21	0.30	977 ppm	3.57	6.99	1387 ppm		1.22
003	2.67	51.8	17.0	5.42	0.63	1.58	0.32	0.14	5.23	7.91	470 ppm	<0.01	1.51
004	2.68	52.6	15.7	5.31	0.61	1.22	0.31	0.26	5.17	7.72	512 ppm	0.01	1.82
005	2.68	53.0	15.5	5.34	0.62	1.44	0.31	0.31	4.82	7.88	721 ppm	0.02	1.42
006	2.69	53.4	15.4	5.38	0.69	1.55	0.27	0.18	4.83	6.85	664 ppm	0.02	1.77
007	2.70	53.6	15.2	5.24	0.64	1.27	0.29	0.19	5.27	7.57	627 ppm	0.03	1.67
008	2.68	54.8	15.9	5.63	0.62	1.30	0.30	0.19	5.43	7.80	520 ppm	0.01	1.61
009	2.71	53.3	15.1	5.50	0.58	1.49	0.31	0.14	5.41	8.44	859 ppm	0.01	1.25
010	2.72	55.1	16.1	5.05	0.63	1.27	0.29	871 ppm	4.73	7.59	0.16	0.03	1.22
011	2.69	58.6	16.8	5.35	0.65	1.29	0.29	0.13	3.34	7.36	147 ppm	0.01	1.50
012	2.69	50.6	13.8	4.98	0.66	1.33	0.29	0.14	4.29	7.74	175 ppm	0.01	1.63
013	2.67	57.7	16.8	4.87	0.66	1.26	0.29	0.14	4.82	7.26	269 ppm	0.02	1.68
014	2.69	56.9	16.3	5.35	0.72	1.63	0.32	644 ppm	4.77	7.91	548 ppm	0.01	1.98
015	2.70	57.1	16.5	5.25	0.68	1.26	0.31	0.14	4.67	8.16	0.12	<0.01	1.52
No. of samples	15	15	15	15	15	15	15	15	15	15	15	15	15
Mean	2.69	56.97	16.34	5.42	0.67	1.40	0.31	0.18	5.03	8.03			1.50
Standard Dev.	0.02	2.61	0.85	0.22	0.04	0.14	0.01	0.05	0.52	0.41			0.23
Minimum	2.66	50.60	13.80	4.87	0.58	1.21	0.27	0.13	3.34	6.85	0.12	0.01	1.16
Maximum	2.72	59.30	17.00	5.63	0.72	1.63	0.32	0.31	5.43	8.45	0.16	0.03	1.98

Table 7: Chemical analysis results of nepheline syenite from various deposits

CHEMICAL COMPOSITION	[1]PILANESBERG RED SYENITE	[2]BULLS RUN	[3]CANADA	[3]NORWAY	[3]USA, Maine Litchfield	[3]CONGO
SiO_2	56.82	52.61	58.800	52.37	60.39	55.44
Al_2O3	22.56	23.86	23.00	23.22	22.51	23.59
Fe_2O3	0.81	0.22	0.80	1.10	0.42	0.44
MgO	0.70	0.11	0.04	0.25	0.13	0.14
CaO	1.44	1.19	0.82	3.11	0.32	1.56
MnO	0.29	0.02	0.05	0.09	0.08	0.15
P_2O5	0.19	0.32	0.01	0.09	-	0.18
K_2O	5.01	6.92	5.20	8.30	4.77	6.26
Na_2O	8.92	8.53	9.40	6.87	8.44	10.20
LOI	1.59	1.30	-	-	-	1.62
Total	98.33	95.08	98.12	95.40	97.06	99.58

[1] Mintek, 2004; [2] Germiquet, 1986; [3] Minnes, 1975

Using rock classification in Table 1, some of the samples can be classified as foyaite. Shand (1932) established that there is Red Syenite within the White Foyaite on the farms Palmietfontein, Zandrivierspoort, and Koedesfontein. Therefore, from these areas samples collected could be the mixture of the two varieties. It is also indicated that the transition between Red Syenite and White Foyaite is gradational. The Red Syenite contains about 30% nepheline, which makes it a product of commercial interest.

Compared with different types of nepheline syenites deposits from other countries in table 8, South African deposits have high nepheline content. This sets South Africa’s few deposits in the same calibre as other deposits worldwide. If issues of concern can be addressed and potential users are willing to use the material, the glass and manufacturing industry can benefit from the advantages that nepheline brings. However, to be able to supply the glass industry, facilities for beneficiation of the raw product must be in place.

Petrographic classification of the samples was conducted using the BGS Rock Classification Scheme by Gillespie and Stiles (1999). The classification is strictly based on descriptive attributes such as proportions of certain minerals and grain size (Gillespie and Stiles, 1999). In this exercise the main emphasis is on composition.

Table 8: Comparison of the petrography of nepheline syenite deposits

MINERALOGICAL COMPOSITION	[1]PILANESBERG RED SYENITE	[2]BULL'S RUN	[3]CANADA		[3]NORWAY	[3]USA, Maine Litchfield
			Hornblende	Biotite	Pyroxene	
Albite $NaAlS_3O_8$	25	60	48.40	52.00	trace	47.80
Microcline $KAlS_3O_8$	20		22.70	18.90	-	16.50
Perthite			minor	minor	57.00	-
Nepheline $(Na,K)AlSiO_4$	30	36	24.90	24.10	37.00	23.70
Biotite $H_2K(Mg,Fe)_3Al(SiO_4)_3$	5		0.10	2.20	trace	5.50
Hornblende $CaMg_2(Al,Fe)_2Si_3O_{12}$	8		3.00		1.00	
Pyroxene			0.20		1.00	
Magnetite $FeO.Fe_2O_3$	4		0.40	0.50	1.00	
Calcite $CaCO_3$	0.5			0.1	2	
Muscovite $(H,K)AlSiO_4$	4			0.7		

[1] Moruo Services, 2004; [2] Germiquet, 1986; [3] Minnes, 1975

The following modal parameters are used in the classification:
Q = Quartz, tridymite, cristobalite.
A = Alkali feldspar: orthoclase, microcline, perthite, anorthoclase.
P = Plagioclase and scapolite.
F = Feldpathoids (foids): nepheline, sodalite, cancrinite, leucite, pseudoleucite.
M = Mafic and related minerals, except for those in QAPF. This includes all micas, amphibole, pyroxene, olivine, opaque and accessory minerals.

The sum of Q, A, P and F must be 100% (Gillespie and Stiles, 1999). Samples in table based on the mineral composition fall into APF diagram.

From table 8, modal parameters required for the APF diagram were determined and plotted in figure 7.

Table 9: Petrographic classification of nepheline-bearing deposits

MODAL PARAMETER	PILANESBERG RED SYENITE		BULL'S RUN	CANADA		NORWAY	USA,
				Hornblende	Biotite	Pyroxene	Maine Litchfield
Q							
A	45.0	4.5	60.0	71.0	71.0	57.0	64.0
P	8.0	22.5	4.0	0.4	1.4	1.0	0.3
F	30.0	32.5	36.0	24.9	24.1	37.0	23.7
M	17.0	40.5		3.7	3.5	5.0	12.0
TOTAL	100	100	100	100	100	100	100

This information was plotted in the AQF diagram and majority of samples including the Pilanesberg Red Syenite plot in the (foid) Monzosyenite zone and two in the (foid) Syenite zone. From this classification it can be concluded that the deposit of interest in the Pilanesberg is in actual fact the nepheline-monzosyenite. However, a detailed petrographic investigation needs to be conducted to be able to determine the extent and size.

On a separate study, a number of samples were submitted to a laboratory for a petrographic classification and the material was classified as a fluorite-bearing-monzo-syenite and comprised of the following minerals:
K-feldspar - 30 to 35%
Plagioclase - 20 to 25%
Biotite & muscovite - 10 to 15%
Hornblende - 10 to 15%
Fluorite - 5 to 10%
Quartz - < 5%
Sphene <2%
Apatite - < 1%
This study agrees with the classification conducted using BGS Rock Classification Scheme by Gillespie and Stiles (1999).

Monzonite is one of three rocks dominated by feldspar, others being anorthosite and Syenite. Monzonite is light coloured and is often confused with granite but granite has quartz >20%. Monzonites with quartz 5-20% are "quartz Monzonites". Less than 5% quartz and the rock is just monzonite. Typical monzonite has the following mineral proportions
Plagioclase - 50-100%
Orthoclase - 10-35%
Mafics - < 10%
Quartz - 0-5%

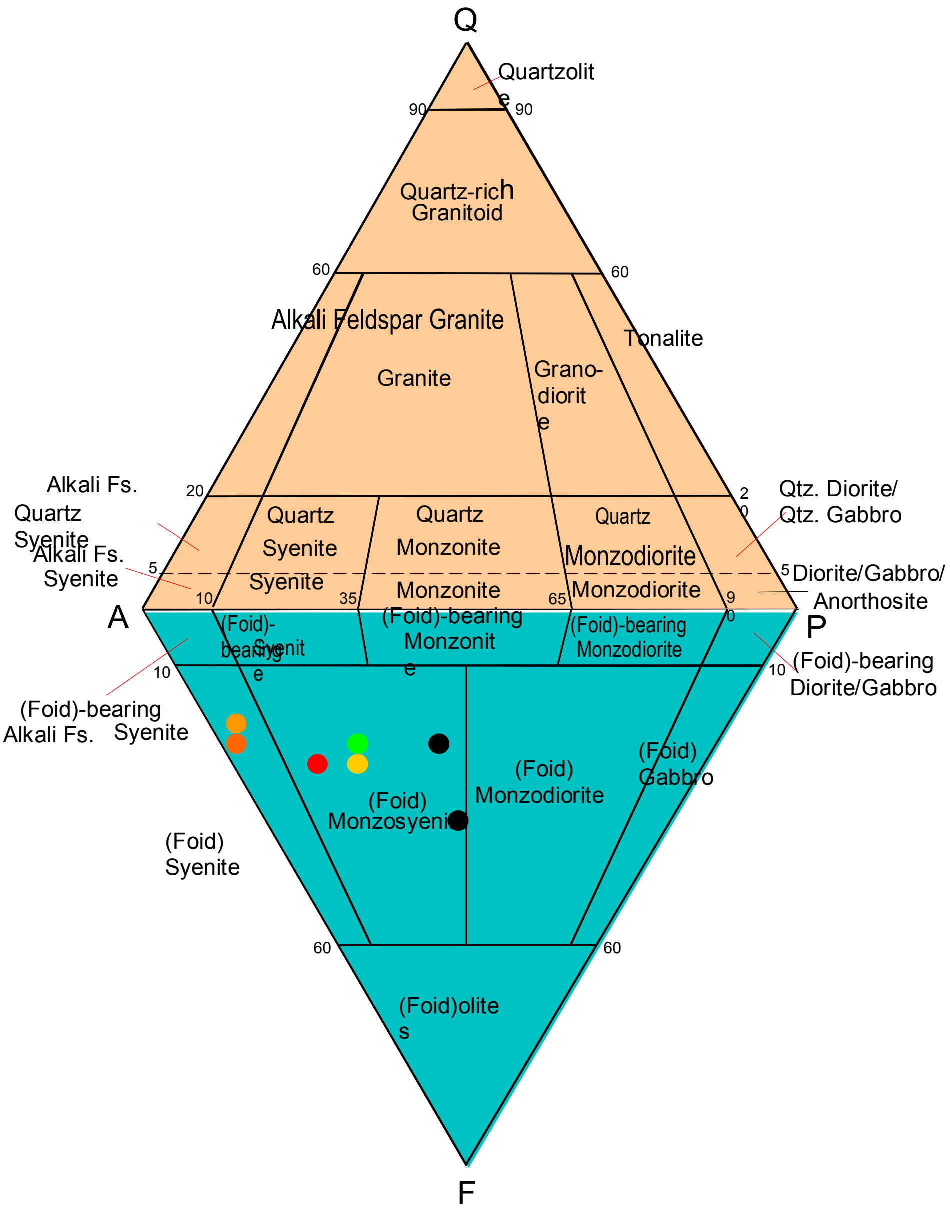

Figure 7: Classification of nepheline-bearing deposits (Gillespie and Stiles,1999)

5.4. Resources and reserves and production rate

A total indicated resource of 10.2 million tons has been estimated from the known dimensions of the deposit as indicated in section 4.2. The estimation was based on the estimated dimensions of the deposit and the density of the material. Dilution is estimated to contribute 5% during quarrying. After mining the outcrop, a pit will be developed to a depth of 50m. It is estimated that approximately % oversize material will be rejected in the quarry. This brings the estimated probable reserve to 9 Mt. At the present demand, to feed a stockpile of 10 to 15 years within a year, a production rate that varies between 750 and 1125 tons per day will be required. The ceramic manufacturer indicated that its monthly consumption is approximately 1500 tons. Therefore, the production rate is determined by the demands for the material in the market, which is at this stage 1500 tons.

5.5. Benchmarking – nepheline vs. feldspar

Feldspars are the most widespread mineral group, contained in approximately 60% of the earth's crust. One of the major challenges to using nepheline is the availability and abundance of feldspar in South Africa. Most of the feldspar in South Africa is mined in the Northern Province, Northern Cape, and Western Province. The Northern Province is the highest producer. In 2003, South Africa produced 57.7 kt of feldspar for both the local and the export markets (Agnello et al, 2003). Table 9 shows South African feldspar production, sales and exports between 1999 and 2003. 2003 saw a 13% decline in production when compared to the previous year. Nepheline sales have not been fully recorded since 1998 (Figure 5).

Table 10: South African production, local sales and export of feldspar (Agnello et al, 2004).

YEAR	PRODUCTION	LOCAL SALES		EXPORT SALES	
	kt	kt	R/t	kt	R/t
1999	**59,3**	**40,0**	**375**	**1,4**	**763**
2000	**67,0**	**52,2**	**397**	**0,8**	**1091**
2001	**66.1**	**70,6**	**382**	**1,2**	**1333**
2002	**66,6**	**61,0**	**432**	**0,5**	**1591**
2003	**57,7**	**57,4**	**521**	**-**	**-**

In 2004, global production of feldspar decreased by 4% to approximately 770 000 tons. There was a notable increase in exports by 8% to 9 630 tons (Potter, 2004). Import records also showed an increase. Table 9 below shows that South Africa is a minor producer of feldspar.

Table 11: World production of feldspar by country – 10 top producers (Potter, 2003).

COUNTRY	2001	2002	2003	2004
Italy	**2,600,000**	**2,500,000**	**2,500,000**	**2,500,000**
Turkey	**1,510,293**	**1.766,887**	**1,800,000**	**1,900,000**
USA	**800,000**	**790,000**	**800,000**	**770,000**
Thailand	**710,543**	**783,733**	**780,000**	**825,000**
France	**650,000**	**650,000**	**650,000**	**650,000**
Germany	**450,000**	**450,000**	**450,000**	**450,000**
Spain	**450,000**	**450,000**	**450,000**	**450,000**
Rep. of Korea	**389,361**	**415,580**	**400,000**	**480,000**
Czech Republic	**373,000**	**401,000**	**350,000**	**400,000**
Egypt	**300,000**	**350,000**	**350,000**	**350,000**
*South Africa	**_66,736_**	**_57,197_**	**_57,343_**	**_53,045_**

* South Africa not in the top 20- it is merely mentioned for benchmarking purposes

The positive trend in the economic cycle of the building industry has an influence on the production of feldspar and nepheline in South Africa. From 2002 to 2003 there was a decline in production of feldspar.

Globally the leading producer of feldspar since 2003 has been Italy. Italy is followed by Turkey and then the USA. The feldspar market has undergone some changes and that is evident in the listed countries and the production level changes (Table 10). For an example, in the USA, there was a slight reduction in the demand of feldspar and that can be attributed to a 3% decline in the production glass containers and changes in the housing industry.

In 2000, Japan produced the largest amount of feldspar, supplying over 28% of the world total of 9.3 million tons. Turkey was the second largest supplier at 13%, followed by the USA at 8% and France at 6%. Overall, world production of feldspar increased 4% compared to 1999 levels. Two trends are expected to negatively impact on the demand for feldspar and nepheline syenite over the next several years:

a) The increasing use of plastic rather than glass containers; and
b) The growing use of recycled glass in glass manufacturing.

In the USA, in 2000, there was a slight reduction in feldspar demand because of a 3% decline in the shipment of glass containers, along with slightly lower housing activities, which was about 4% lower than in 1999 (Potter, 2003). Of the USA feldspar sold or used in 2000, 66% went into the manufacture of glass, including glass containers and glass fibre. Ceramics, including electrical insulators, sanitary ware, tableware and tile and other uses, such as fillers, accounted for the remaining 34%. By the end of 2000, prices for ceramic-grade sodium feldspar at 170-250 mesh size fraction, had increased by about $3 per ton at both the lower and upper ends of the price range to about $67-80 per ton. Ceramic-grade feldspar, 200 mesh, increased by about $7 per ton compared with the price earlier in the year to about $139 per ton. This was also a $34 increase per ton compared with the price in December 1999. Glass-grade feldspar, 30 mesh, increased by about $8 per ton at the upper end of its range to $57 per ton (Potter, 2003).

Despite the popularity of feldspar, nepheline has pronounced advantages. In glass and ceramics nepheline provides alkalis that act as a flux to lower the melting temperature for a glass or ceramics mixture. This prompts faster melting and fuel savings. In glass, nepheline supplies alumina, which improves thermal endurance, increases chemical durability, and resistance to scratching and breaking. It is also favoured in coatings because of its low silica content and is an effective in-can buffer (Cuillo and Robinson, 2003). The basic properties of feldspar and nepheline are compared in Table 12 below.

Table 12: Basic properties of feldspar and nepheline (Cuillo and Robinson, 2003).

MINERAL	FORMULA	REFRACTIVE INDEX	SPECIFIC GRAVITY	MOHS HARDNESS
Orthoclase	**$KAlSi_3O_8$**	**1.52**	**2.57**	**6**
Microcline	**$KAlSi_3O_8$**	**1.53**	**2.54-2.57**	**6**
Albite	**$NaAlSi_3O_8$**	**1.53**	**2.62**	**6**
Nepheline	**$(Na,Al)SiO_4$**	**1.54**	**2.60-2.65**	**5.5-6**
Anorthite	**$CaAl_3Si_3O_8$**	**1.56**	**2.76**	**6**

As mentioned earlier, most nepheline syenite deposits in South Africa are located in uneconomic locations and are not big enough to compete with feldspar which is the most widespread mineral group.

CHAPTER 6

6. PROJECT EVALUATION

To establish the financial viability of the deposit at a prefeasibility level, a thorough investigation of the size of the deposit and its quality is of vital importance. A financial model based on opencast mining will be developed and incorporate the needs of the market. Several options will be explored on the basis of historical information. The outsourcing of major functions, such as transportation of material to the client will be considered. Factors such as beneficiating the material and the cost implications, instead of supplying an unbeneficiated product will also be addressed.

On the basis of the parameters of the project, a qualitative risk and sensitivity analysis will be conducted. This will give an idea of the risks that could likely be related to this kind of project, their probability of occurrence, and the impact they are likely to have on the project. A sensitivity analysis will show how changes in the variables used in discounted cashflow (DCF) affect the financial criterion such as the net present value (NPV), internal rate of return (IRR) and the payback period.

6.1. Mining of nepheline syenite

Mining and the actual method used are based on the following assumptions:

a) The material produced is suitable for ceramics manufacturing;
b) Total production sold per month is 1500 tons;
c) Quarry sorting will be 10% of blasted material;
d) Beneficiation will yield 75% of product at a ceramics-grade specification; and
e) The selling price is R450/ton F.O.R. for unbeneficiated product and R800/ton F.O.R. for beneficiated product.

The material will initially be obtained from a quarry where blasting will be required. Ten percent machine sorting will be conducted in the quarry and dumped as waste, while 90% will be delivered to the beneficiation plant for further processing.

Machinery and equipment that are required include the following:

a) Drill machine
b) Compressor
c) Fuse magazine
d) Explosives truck
e) Haulage truck
f) Front end loader

Acquisition of this machinery will be funded by debt and will be part of the capital costs. . After 6 years, machinery will be replaced and the company will fund the transaction on its own.

6.2. Beneficiation

Beneficiation takes the form of crushing, milling, screening, wet high-intensity magnetic separation, and drying. The fragmented rock from the quarry is crushed and milled to produce the required size. The sized product is passed over low- and high-intensity separators. The magnetic fraction containing magnetite, ilmenite, sphene and entrapped nepheline is stockpiled to explore its potential value. The non-magnetic product will be loaded on trucks by contractors and transported for a distance of about one hundred kilometres to the client. The equipment that is suitable for the operation comprises:

a) Jaw crusher
b) Cone crusher
c) Rod mill
d) Whims separator
e) Drying plant
f) Conveyors
g) Pumps and installations
h) Plant house

For the unbeneficiated product, the Run-Of-Mine (ROM) will be crushed, milled and screened to get the required specification and no further processing will be conducted.

6.3. Rehabilitation programme

Rehabilitation is considered an essential part of the planning process hence an environmental impact assessment is carried out before mining begins. A rehabilitation fund will be established at R1.75 per ton (ROM). And the amount will be used as required during and after the mining activity has been completed. The rehabilitation activity will be outsourced to a service provider that specialises in this. The rehabilitation process will be structured and carried out in four phases.

Phase 1: This is the rehabilitation planning phase. The quarries are handed over as flat quarry floor excavated to a minimum of 30 – 50 cm above the ground water table.

Phase 2: Landscape creation – the land is prepared for planting. This includes in this particular case hard landscaping. At this stage overburden and topsoil are applied and planting holes are created.

Phase 3: This is the initial greening phase. This is the main planting stage and it will include grassing, planting of trees. It also includes attracting suitable wildlife to speed up the seeding and the fertilization of the bare ground. Game faming activities are closely linked to rehabilitation and this is more relevant to the site as the area is located immediately south of a heritage site that is used for game farming. Monkeys, birds, bats all assist with seed dispersal.

Phase 4: In this stage vegetation is thinned to create an environment in which a diverse species will thrive.

Rehabilitation is complete after phase 4. New plants and animals can still be introduced and harvesting and management is conducted to keep the ecosystem in a balanced state and to maintain economic sustainability.

6.4. Costs

Mining costs for this project are categorised into capital and operating costs. Capital and operating costs are summarized below:

a) Capital Costs

Capital equipment costs apply to both beneficiated and unbeneficiated material.

[1]Site preparation	R500 000
Quarry: Drill machine	R500 000
Compressor	R200 000
Fuse magazine	R50 000
Explosives truck	R50 000
Haulage truck	R300 000
Front end loader	R400 000
[2]Feasibility Study	R3 000 000
Total	**R5 000 000**

Beneficiation

The section below only applies to beneficiated material

Jaw crusher	R1 200 000
Cone crusher	R800 000
Rod mill	R500 000
Whims	R1 500 000
Drying	R600 000
Conveyors	R200 000
Pumps and installation	R400 000
Plant house 100mx50m	R500 000
Total	**R4 700 000**

b) Operating costs

i. Production

Quarry production 2500 t/m (S.G. 2.6) 961 m^3/m

Drilling	R2.50/m^3
Explosives	R1.50
Loading	R1.00
Haulage	R2.00
	R7.00/m^3

R2.69/t ore

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[1] Includes office building

[2] Includes Environmental Impact Assessment

Processing

Crushing	R1.00/t
Grinding	R1.60/t
Whims	R0.50/t
Drying	R0.50/t
	R3.60/t ore

ii. Transport

R1.10/t/km

iii. Rehabilitation fund contributions

R1.75/t

c) Labour per month

Manager	1	R75 000 /m
Engineer	1	R50 000/m
Supervisors	2	R10 000/m
Truck driver	2	R7 500/m
Engineering assistants	4	R12 000/m
Drilling & explosives	2	R7 500/m
Crusher operators	2	R7 000/m
Grinding	1	R3 000/m
Whims	1	R3 000/m
Drying	4	R12 000/m
Administrator	1	R3 000/m
Total		**R194 000/m**

6.5. Financial evaluation

Financial viability of the deposit includes looking at the costs of production, commodity price, capital required and the production rate. Most importantly an undeveloped deposit must be assessed for its “place value”. This is a problem in South Africa, as most deposits are located far away from the market, which is Gauteng. The “place value” includes transportation costs to carry the product to the market, the nature of markets, the specific product demand, the capital and production costs.

In South Africa, the cost per ton for nepheline syenite varies between R350 and R500 depending on quality for unbeneficiated material and up to R800 for beneficiated material. Production costs generally include drilling and blasting of the material to a coarser size, and this material is later crushed and milled to the size required by the client. Most companies more especially ceramics producers, consume an average of 1500 tons per month of nepheline at a size less than 10mm. Costs that are reflected in a cashflow are associated with developing, mining, and processing the material. Further details usually include exploration, mining, processing and marketing.

Financial evaluation of this project was undertaken on the basis of the intention to mine the deposit. In that case internal rate of return (IRR) and net present value (NVP) are important. Evaluation was conducted on both the beneficiated and unbeneficiated material. The reason for evaluating both is that the ceramics manufacturer required a raw product that will be processed in its plant facility. The glass manufacturer was more inclined towards a beneficiated product processed to its specifications. The main difference in the financial models will be the exclusion of some of the capital outlay, processing costs and working costs in an evaluation of unbeneficiated material. For this study, a price of R450/ton would be used for the unbeneficiated material and R800/ton for the beneficiated product.

6.5.1. Inflation rate

Inflation is the percentage increase in the price of goods and services annually. At the time of writing this report, the inflation rate was 4%. This rate was applied to the following parameters of the discounted cashflow model:

a) Selling price
b) Operating cost per unit
c) Transport costs
d) Corporate expenses
e) Capital costs

It is assumed that the inflation rate will average at 4% in the next 10 years.

6.5.2. Discount rate

The discount rate used to calculate the NPV is 14%. It is made up of the bond rate and the risk factor associated with the project. Currently the bond rate is approximately 8 % (E194 = 7.82%). The bond rate is made up of inflation and the country risk. The inflation rate is currently at 4% (3.9) and the country risk can be rounded off to 4% too. The risk of the project is at 6%, which is a figure that is commonly assigned to the development of a new project. The NPV was also calculated using discount rates at 12%, 16% and 18% to account for inaccuracy of estimations of items such as inflation rate.

6.5.3. Interest rate

The bank's lending prime rate is currently 10.5%. When the company borrows capital, the interest rate paid on that capital is prime rate and additional 1.5%. In this project, 12% is therefore used as an interest rate paid on the capital borrowed.

6.5.4. Royalty

The Royalty Bill imposes a quarterly charge on holders of mineral rights for the extraction and transfer of South African mineral resources. This Bill recognizes that the nation is entitled to a consideration for the extraction of its non-renewable mineral resources. The royalty is a charge in the form of a certain percentage of consideration withheld on the gross sales value of the mineral commodity extracted. The royalty is levied in addition to income tax but scores as a deduction, as it constitutes a deductible expense in the production of income. The charging regime contained in the Royalty Bill strikes a balance between the need for adequate compensation and the imperative of maintaining the international competitiveness of the mining sector. The royalty rates fall well within internationally competitive margins that can be sustained for the foreseeable future. The royalty rates range from one per cent to eight per cent depending on the mineral commodity. The more notable mineral resources such as gold and platinum are set at rates of 3 and 4 per cent respectively and below. The Royalty Bill charges the highest rate of 8 per cent on diamonds. The royalty charge for mining industrial minerals is 1%. This figure is applied on the discounted cashflow and as indicated in table 13 and 15 is deducted from the gross revenue.

6.5.5. Tax rate

Mining companies for the last 6 years have been paying an income tax that ranges between 30 and 38% depending on certain exclusions applicable. Without exclusions, companies now pay an income tax of 29%, which is applied in this project. The tax is deducted after paying off the debt. In the first year of this project, it is deducted on the remaining amount after paying the debt.

6.5.6. Beneficiated product (Scenario 1)

6.5.6.1. Discounted cashflow model

A simple Microsoft Excel discounted cashflow model was used to assess the financial viability of the project. The following section will look at the inputs and outcomes of the project evaluation.

At a selling price of R800, gross revenue generated from producing 18000 tons is R14.40 million. Royalties on gross revenue will be payable to the government at the proposed rate 1%. This is based on the assumption that the Mining Royalty Bill will be in place by the year 2007. The total operating cost of producing per ton will be R6.29, which translates to an average operating cost of approximately R156 000. This figure applies to the year 1 of production and escalates annually by 4% as indicated in section 6.5.1. Annual profit is expected in year two which is the first year of production, to be R7.18 million. Transport costs have been quoted to be R1.10 per ton per kilometre. This function will be outsourced so that the company can concentrate on its core function of mining. The annual costs for transportation will be approximately R3.17 million. The distance to the glass manufacturer is 160 km.

Capital outlay required has been estimated at R9.70 million. One hundred percent of the project will be funded by debt, which will be payable at the end of the first year of production. The area of development has no infrastructure. Therefore a substantial amount of site preparation is needed and that requires a high capital outlay. Capital expenditure incurred will be for the mining machinery, plant infrastructure, office buildings and overheads. The cost per ton as quoted for both mining and processing will initially be R2.69 and R3.60 respectively. Over a period of 10 years, with mining having commenced in year two the financial variables representing the projects are as follows:

- *Discount rate* = *14 %*
- *NPV* = *R20.30 million*
- *IRR* = *66%*
- *Payback period (Months)* = *23.8*
- *Maximum cash exposure* = *-R1.66 million*

The DCF model is provided as Table 12.

The Net Present Value (NPV) of the project is positive and approximately R20 million. The internal rate of return (IRR) indicates that there will be a high return generated by the project. IRR is the rate of return when the NPV is zero. At the present production rate of 18000 sales ton per annum, the R9.70 million debt will be paid back in 24 months (Figure 8).

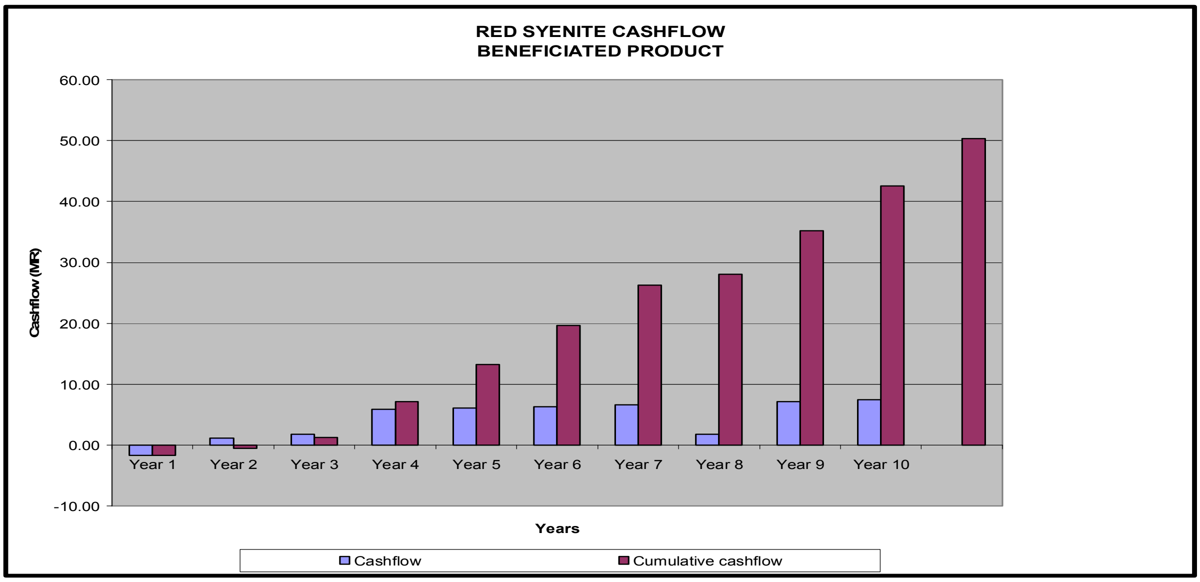

Figure 8: Beneficiated product cashflow

A Rule of Thumb based on the economic characteristics of the project by the investor specifies that "the cashflow should pay back the capital in three years" (Rudenno, 1998). This project conforms to the investor's rules. If the production rate which is influenced by the demand of the material declines, the payback period will get closer to three years. And this is of a concern when dealing with industrial minerals, as the annual production should not exceed the market demand. The NPV at discount rates of 12%, 16% and 18% are R23.09, R17.89 and R15.80. This is an indication that the project is robust.

6.5.6.2. Sensitivity analysis

In a sensitivity analysis one parameter is changed at a time and corresponding values of NPV, IRR, and payback period are calculated. Variations in these values are assessed on how they affect the project. In this case, parameters that are changed systematically are:

a) Capital expenditure (Capex)
b) Operating costs
c) Production rate
d) Selling price per ton (selling price)
e) Transport costs

Systematic changes are done in the discount cashflow model and the financial variables are calculated the same way as for the project evaluation above. The effect of these variations will be evident in IRR, NPV, and payback period (Table 14). The base parameters were changed by up to -30% to 30% and the effect in financial variables was observed. Table 14 shows what the IRR, NPV, and payback will be when various changes are applied. For example, in the first table 89% IRR is obtained when capital is reduced by 30%. When looking at the effect of a change in transport costs, a 10% increase in transport costs will decrease the IRR to 63.17%.

Table 13: Discounted cashflow model for the beneficiated product

SCENARIO 1

10 YEAR FINANCIAL MODEL

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Total
ROM	t		24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	240,000
Yield	%		75	75	75	75	75	75	75	75	75	75	75
Sales	t		18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	180,000
Selling price	R/t		800.00	832.00	865.28	899.89	935.89	973.32	1012.26	1052.75	1094.86	1138.65	
GROSS REVENUE	R	-	14,400,000	14,976,000	15,575,040	16,198,042	16,845,963	17,519,802	18,220,594	18,949,418	19,707,394	20,495,690	172,887,943
Less Royalties (1%)	R	-	144,000	149,760	155,750	161,980	168,460	175,198	182,206	189,494	197,074	204,957	1,728,879
NET REVENUE	R	-	14,256,000	14,826,240	15,419,290	16,036,061	16,677,504	17,344,604	18,038,388	18,759,923	19,510,320	20,290,733	174,616,822
Unit Revenue	R/t	-	792	824	857	891	927	964	1002	1042	1084	1127	
OPERATING COSTS	R	-	150,960	156,998	163,278	169,809	176,602	183,666	191,013	198,653	206,599	214,863	1,812,442
Unit cost	R/t	-	6.29	6.54	6.80	7.08	7.36	7.65	7.96	8.28	8.61	8.95	
CASH OPERATING PROFIT	R	-	14,105,040	14,669,242	15,256,011	15,866,252	16,500,902	17,160,938	17,847,375	18,561,270	19,303,721	20,075,870	169,346,621
Transport costs per unit	R/t/km		1.10	1.14	1.19	1.24	1.29	1.34	1.39	1.45	1.51	1.57	
Transport costs	R/t		3,168,000	3,294,720	3,426,509	3,563,569	3,706,112	3,854,356	4,008,531	4,168,872	4,335,627	4,509,052	38,035,347
Corporate Expenses	R	-500,000	3,240,000	3,369,600	3,504,384	3,644,559	3,790,342	3,941,955	4,099,634	4,263,619	4,434,164	4,611,530	38,399,787
Rehabilitation Fund (R1,75/t)	R	-	42,000	43,680	45,427	47,244	49,134	51,099	53,143	55,269	57,480	59,779	504,256
Capital Expenditure	R	-9,700,000	-	-	-	-	-	-	-	-	-		-9,700,000
Replacement of machinery	R								-7,212,318				
PROFIT BEFORE TAX	R	-10,200,000	7,655,040	7,961,242	8,279,691	8,610,879	8,955,314	9,313,527	2,473,749	10,073,510	10,476,451	10,895,509	74,494,912
Taxable Income	R	-	1,641,040	2,529,242	8,279,691	8,610,879	8,955,314	9,313,527	2,473,749	10,073,510	10,476,451	10,895,509	73,248,912
Taxable @ 29%	R	-	475,902	733,480	2,401,110	2,497,155	2,597,041	2,700,923	717,387	2,921,318	3,038,171	3,159,698	21,242,184
PROFIT AFTER TAX	R	-10,200,000	7,179,138	7,227,762	5,878,581	6,113,724	6,358,273	6,612,604	1,756,362	7,152,192	7,438,280	7,735,811	63,452,727
Debt funding	R	9,700,000	-4,850,000	-4,850,000									
Interest paid	R	-1,164,000	-1,164,000	-582,000									
NET CASH FLOW	MR	-1.66	1.17	1.80	5.88	6.11	6.36	6.61	1.76	7.15	7.44	7.74	50.34
CUMULATIVE CASHFLOW	MR	-1.66	-0.50	1.30	7.18	13.29	19.65	26.26	28.02	35.17	42.61	50.34	
Discount rate (%)	14	12	16	18									
NPV (MR)	20.30	23.09	17.89	15.80									
IRR	66%												
Payback Period (Months)	23.8												
Maximum cash exposure (MR)	-1.66												

Table 14: Sensitivity analysis

IRR Variations (%)					
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	89.01	66.08	37.87	73.19	27.82
-20%	79.58	65.96	47.70	70.71	41.73
-10%	71.99	65.84	56.90	68.22	54.11
0%	65.72	65.72	65.72	65.72	65.72
+10%	60.42	65.60	74.26	63.18	76.86
+20%	55.87	65.48	82.63	60.63	87.72
+30%	51.91	65.36	90.85	58.05	98.37
NPV Variations (MR)					
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	22.67	20.47	8.07	23.86	4.30
-20%	21.88	20.42	12.15	22.67	9.64
-10%	21.09	20.36	16.23	21.49	14.97
0%	20.30	20.30	20.30	20.30	20.30
+10%	19.51	20.25	24.38	19.12	25.64
+20%	18.72	20.19	28.45	17.93	30.97
+30%	17.93	20.13	32.53	16.75	36.30
Payback Variations (Months)					
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	16.6	23.7	42.5	21.1	56.1
-20%	19.0	23.8	33.7	22.0	38.7
-10%	21.4	23.8	27.9	22.9	29.5
0%	23.8	23.8	23.8	23.8	23.8
+10%	26.3	23.9	20.8	24.9	20.0
+20%	28.8	23.9	18.4	26.1	17.2
+30%	31.3	24.0	16.6	27.3	15.1

From Figure 9 below, it is observed that capital, production rate, and selling price have a higher influence on the IRR than other parameters do. The IRR increases with the reduction in capital and is reduced when the selling price is reduced. Another observation was that an increase in operating costs reduces the IRR. Transport and operating costs have a minimum effect on the IRR.

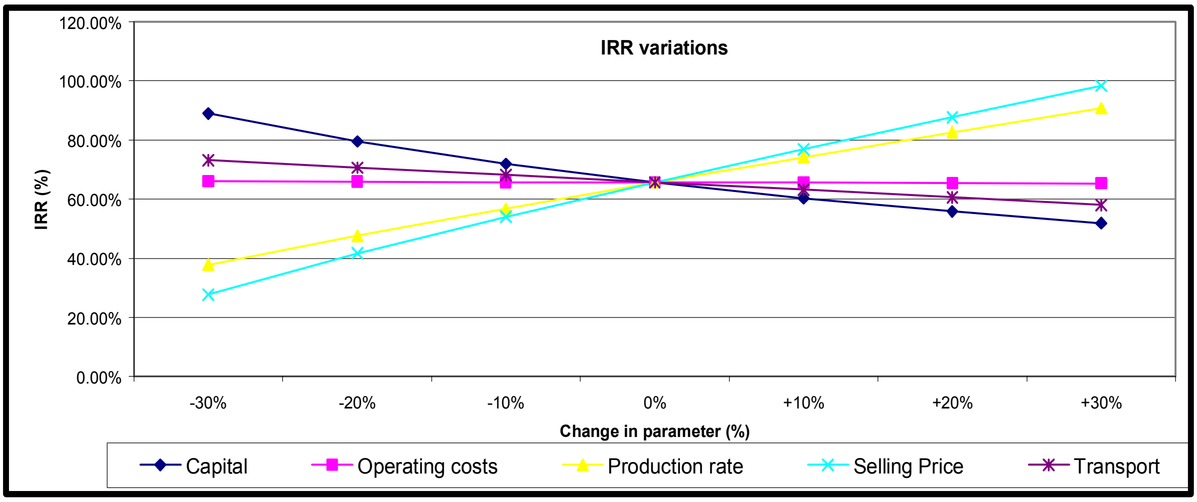

Figure 9: Sensitivity analysis showing variations in IRR

Figure 10 below represent graphically the effect the change of parameters will have on the NPV. The production rate and selling price have the highest influence on NPV obtained. A reduction in the production rate will reduce the NPV, while the increase in selling price will increase the value of the project. A decrease in selling price will obviously affect the NPV negatively. This could happen as a result of the availability of other substitutes that could influence prices to go down, or a decrease in the demand of the product, or an oversupply in the market. From the figure it is observed that capital, operating, and transport costs have a minimum influence on the NPV. However, a combination of these parameters could have a significant negative effect on the project.

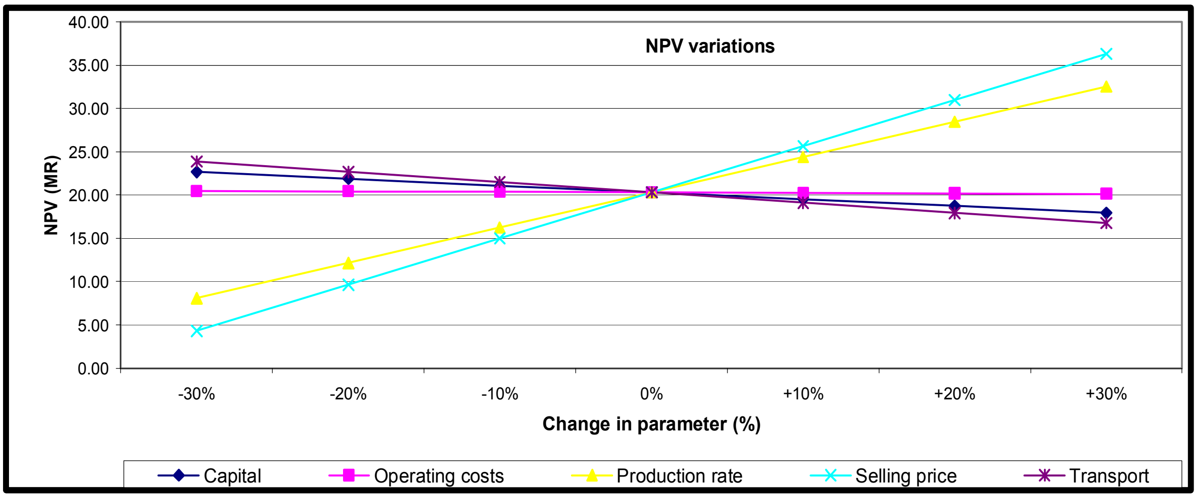

Figure 10: Sensitivity analysis showing variations in NPV

In Figure 11, it is evident that the production rate and the selling price have a major influence on how long it will take to pay back the debt. A 30% reduction in the selling price might increase the payback period to 56 months. Capital, operating and transport costs have a minimum influence on the payback time. A stable price and a constant or increasing demand of the product will keep the project healthy and payable in one year. A reduction in the capital outlay will also obviously reduce the payback term, assuming production rate does not decrease.

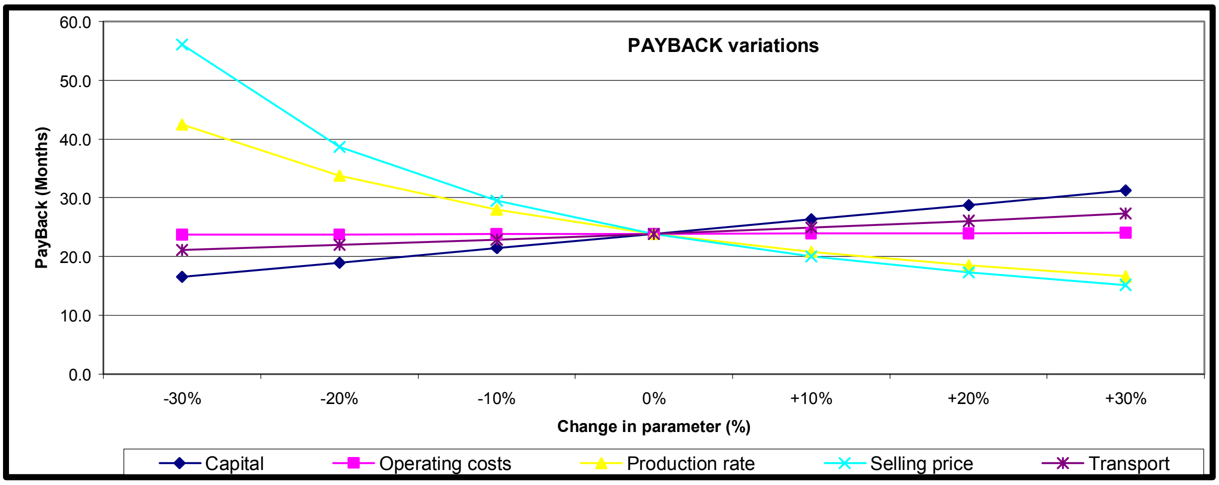

Figure 11: Sensitivity analysis showing variations in payback period

From sensitivity analysis it can be concluded that the project is most sensitive to changes in capital, production rate and the selling price.

6.5.7. Unbeneficiated product (Scenario 2)

6.5.7.1. Discounted cashflow model

The unbeneficiated product will be the produced by crushing and milling of the ROM to the required size. From the milling plant the material will be loaded into trucks and transported to the client.

On evaluating the production of the raw material, parameters that are involved are similar to those for the beneficiated product. At a selling price of R450 per ton, the gross revenue obtained is R8.10 million ton in the first year of production (Table 15). The profit after tax in the first year is approximately R3.41 million. Considering the capital of R5.00 million, a significant portion of the profit will be used to pay back that debt at an interest rate of 12%. The payback period is approximately 25 months and this is because this is a low value material, as expected it will take longer to pay back than scenario 1. Cashflow is positive from the first year of production and the year with a negative cashflow is the commissioning year (Figure 12). The project has an ability to be profitable in the first year of production. The NVP as in the beneficiated case was calculated from the DCF as in Table 15.

Financial variables obtained from a discounted cashflow model are as follows:

- *Discount rate* = *14 %*
- *NPV* = *R9.21 million*
- *IRR* = *57%*
- *Payback Period (Months)* = *25.5*
- *Maximum Cash Exposure* = *-R1.10 million*

The NPV at discount rates of 12%, 16% and 18% is R10.55, R8.06 and R7.06 million respectively.

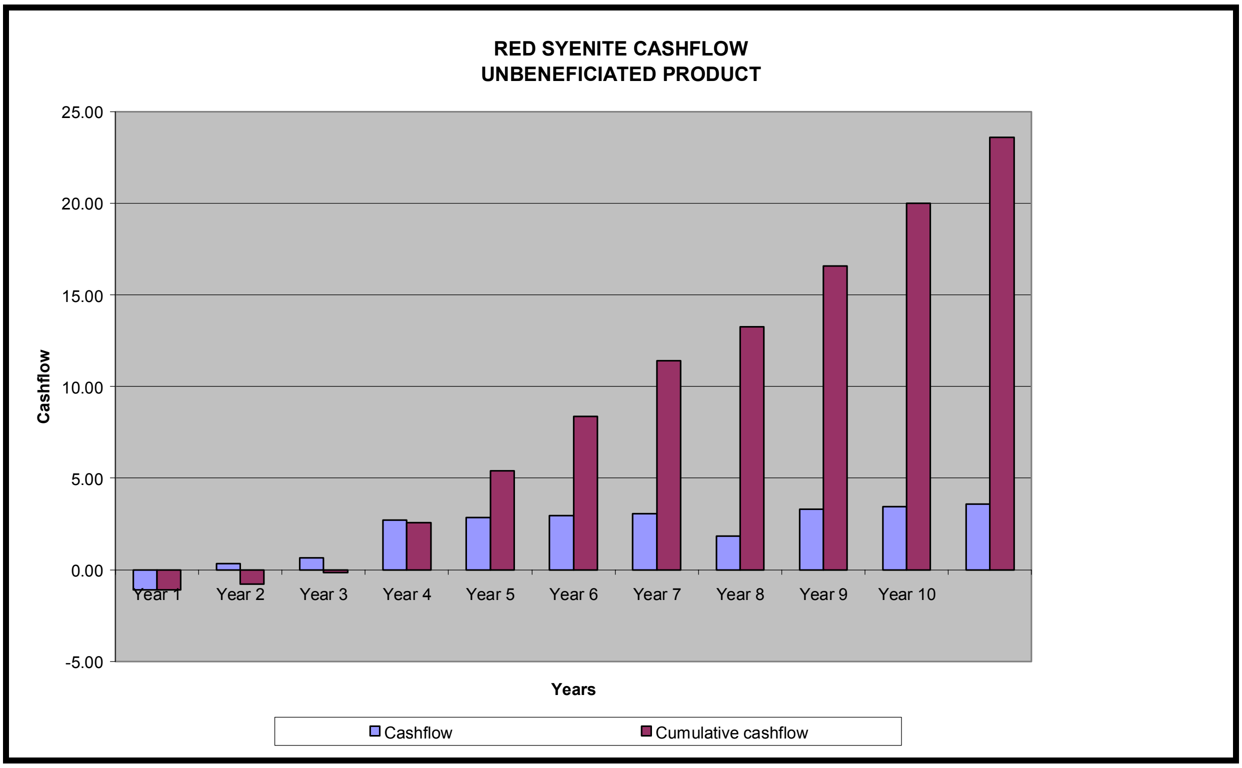

Figure 12: Unbeneficiated product cashflow

6.5.7.2. Sensitivity Analysis

Systematic changes are applied to capital, operating costs, production rate, selling price and transport costs. The effect of these changes is evident in IRR, NPV and payback period (Table 16). The base parameters were changed by up to -30% to 30% and the effect on the financial variables is demonstrated in figures 13, 14 and 15.

In table 16, it is observed that a reduction in capital outlay, transport costs, and operating costs will increase the IRR. These will also have a positive influence on the NPV as well as the payback period.

Table 15 : Discounted cashflow model for the unbeneficiated product

SCENARIO 2

10 YEAR FINANCIAL MODEL

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Total
ROM	t		21,180	21,180	21,180	21,180	21,180	21,180	21,180	21,180	21,180	21,180	211,800
Yield	%		85	85	85	85	85	85	85	85	85	85	85
Sales	t		18,003	18,003	18,003	18,003	18,003	18,003	18,003	18,003	18,003	18,003	180,030
Selling price	R/t		450	468.00	486.72	506.19	526.44	547.49	569.39	592.17	615.86	640.49	
GROSS REVENUE	R	-	8,101,350	8,425,404	8,762,420	9,112,917	9,477,434	9,856,531	10,250,792	10,660,824	11,087,257	11,530,747	97,265,676
Less Royalties (1%)	R	-	81,014	84,254	87,624	91,129	94,774	98,565	102,508	106,608	110,873	115,307	972,657
NET REVENUE	R	-	8,020,337	8,341,150	8,674,796	9,021,788	9,382,659	9,757,966	10,148,284	10,554,216	10,976,384	11,415,440	96,293,019
Unit Revenue	R/t	-	446	463	482	501	521	542	564	586	610	634	
OPERATING COSTS	R	-	56,974	59,253	61,623	64,088	66,652	69,318	72,091	74,974	77,973	81,092	684,038
Unit cost	R/t	-	2.69	2.80	2.91	3.03	3.15	3.27	3.40	3.54	3.68	3.83	
CASH OPERATING PROFIT	R		7,963,362	8,281,897	8,613,173	8,957,700	9,316,008	9,688,648	10,076,194	10,479,242	10,898,411	11,334,348	95,608,981
Transport costs per unit	R/t/km		1.10	1.14	1.19	1.24	1.29	1.34	1.39	1.45	1.51	1.57	
Transport costs	R/t		1,980,330	2,059,543	2,141,925	2,227,602	2,316,706	2,409,374	2,505,749	2,605,979	2,710,218	2,818,627	23,776,054
Corporate Expenses	R	-500,000	2,400,000	2,496,000	2,595,840	2,699,674	2,807,661	2,919,967	3,036,766	3,158,236	3,284,566	3,415,948	28,314,657
Rehabilitation Fund (R1,75/t)	R		37,065	38,548	40,090	41,693	43,361	45,095	46,899	48,775	50,726	52,755	445,006
Capital Expenditure	R	-5,000,000	-	-	-	-	-	-	-	-	-		-5,000,000
Replacement of machinery	R								-1,897,979				
PROFIT BEFORE TAX	R	-5,500,000	3,545,967	3,687,806	3,835,318	3,988,731	4,148,280	4,314,211	2,588,801	4,666,251	4,852,901	5,047,017	35,175,285
Taxable Income	R	-	445,967	887,806	3,835,318	3,988,731	4,148,280	4,314,211	2,588,801	4,666,251	4,852,901	5,047,017	34,775,285
Taxable @ 29%	R	-	129,331	257,464	1,112,242	1,156,732	1,203,001	1,251,121	750,752	1,353,213	1,407,341	1,463,635	10,084,833
PROFIT AFTER TAX	R	-5,500,000	3,416,637	3,430,342	2,723,076	2,831,999	2,945,279	3,063,090	1,838,049	3,313,038	3,445,560	3,583,382	30,590,452
Debt funding	R	5,000,000	-2,500,000	-2,500,000									
Interest paid @ 12%	R	-600,000	-600,000	-300,000									
NET CASH FLOW	MR	-1.10	0.32	0.63	2.72	2.83	2.95	3.06	1.84	3.31	3.45	3.58	23.59
CUMULATIVE CASHFLOW	MR	-1.10	-0.78	-0.15	2.57	5.40	8.35	11.41	13.25	16.56	20.01	23.59	
Discount rate (%)	14	12	16	18									
NPV (MR)	9.21	10.55	8.05	7.05									
IRR	57%												
Payback Period (Months)	25.5												
Maximum cash exposure (MR)	-1.10												

Table 16: Sensitivity analysis

			IRR Variations (%)		
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	76.03	57.46	28.13	65.93	15.31
-20%	68.49	57.37	38.57	63.05	31.41
-10%	62.34	57.29	48.14	60.14	44.87
0%	57.20	57.20	57.20	57.20	57.20
+10%	52.82	57.12	65.93	54.23	68.93
+20%	49.04	57.03	74.45	51.21	80.29
+30%	45.73	56.95	83.55	48.15	91.42
			NPV Variations (MR)		
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	10.29	9.27	2.54	11.43	0.21
-20%	9.93	9.25	4.76	10.69	3.21
-10%	9.57	9.23	6.98	9.95	6.21
0%	9.21	9.21	9.21	9.21	9.21
+10%	8.85	9.19	11.43	8.47	12.21
+20%	8.49	9.17	13.66	7.73	15.21
+30%	8.12	9.15	15.95	6.99	18.21
			Payback Variations (Months)		
% Change	**Capital**	**Operating Costs**	**Production rate**	**Transport**	**Selling Price**
-30%	17.9	25.4	50.7	21.9	77.4
-20%	20.4	25.4	38.1	23.0	46.1
-10%	23.0	25.5	30.6	24.2	32.8
0%	25.5	25.5	25.5	25.5	25.5
+10%	28.0	25.5	21.9	27.0	20.8
+20%	30.5	25.6	19.2	28.7	17.6
+30%	33.0	25.6	17.8	30.6	15.3

Figure 13 indicates that capital, production rate and selling price have a high influence on the IRR, as for the beneficiated product. When the selling price is analysed, it is observed that a maximum reduction in capital costs will produce an increase in IRR to 77%. A 20% increase in the production rate will increase the IRR to approximately 75%. The trends are similar to the sensitivity for beneficiated product, where capital outlay, production rate and selling price have a significant influence on the IRR. Transport and operating costs have a smaller influence on the base IRR. It is observed that the slope of the line representing transport cost is slightly higher than for the first scenario. This is because the transport cost is applied to a lower value material.

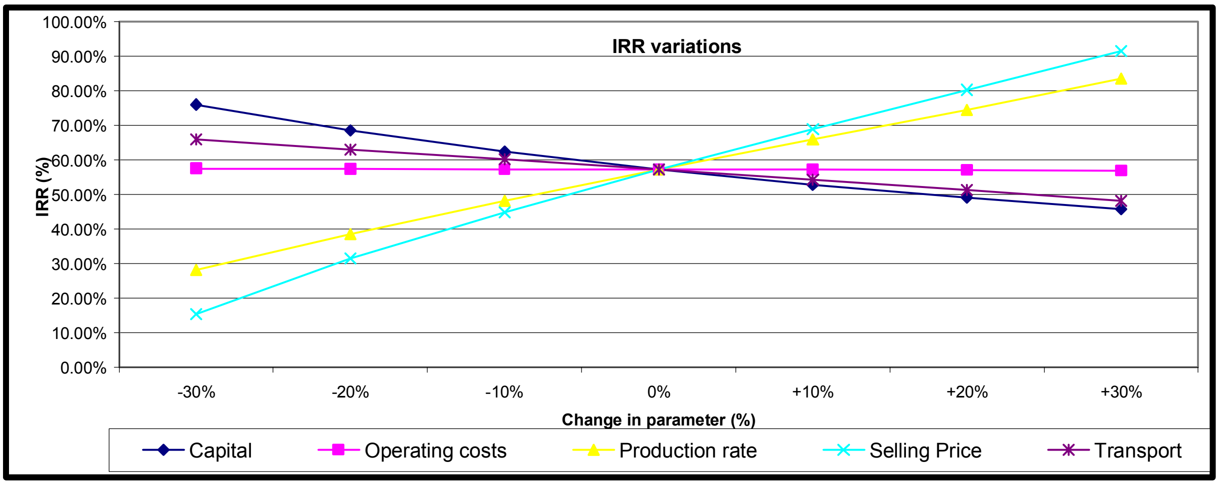

Figure 13: Sensitivity analysis showing variations in IRR

Figure 14 below represents graphically the effect the change of parameters will have on the NPV. Similar to the IRR, production rate and selling price have the highest influence on NPV obtained. A decrease in both of these parameters will lead to a decrease in NPV, and the opposite is also true. A reduction in the operating costs will increase in NPV, and a decrease in transport costs will do likewise.

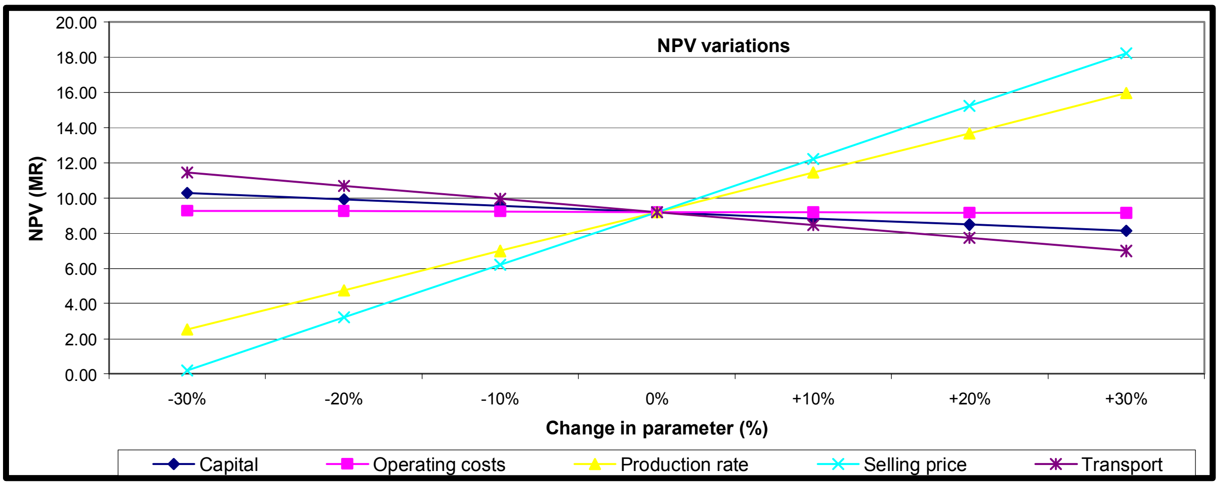

Figure 14: Sensitivity analysis showing variations in NPV

In Figure 15, as with other variables discussed above, capital, production rate, and selling price have a major influence on how long it will take to pay back the debt. A 30% increase in the selling price indicates that the payback period will be decreased to about 15.3months, whilst a 30% reduction in the selling price will increase the payback period to 77 months, which exceeds the planned 25 months.

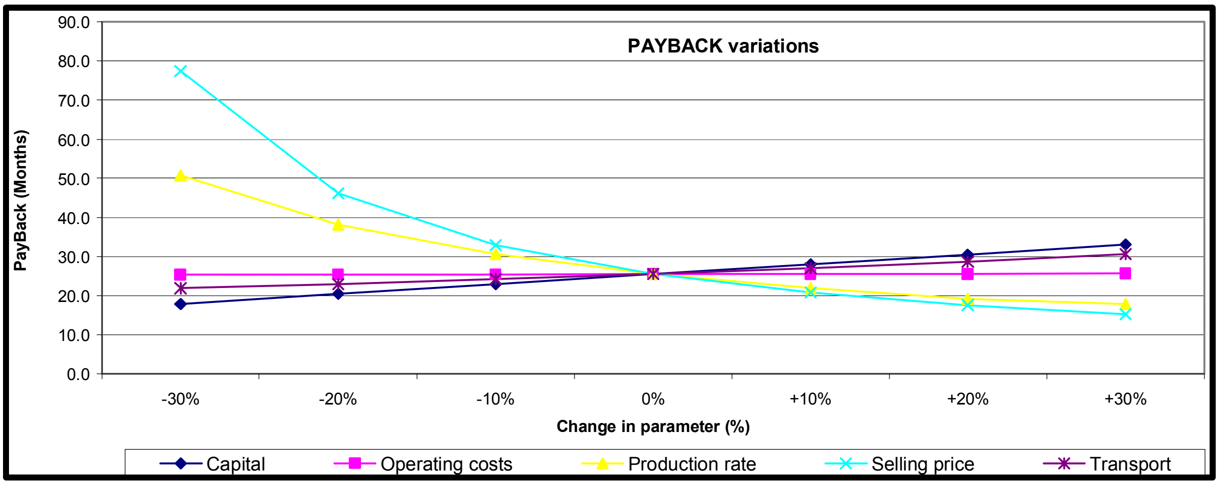

Figure 15: Sensitivity analysis showing variations in payback period

To minimise drastic changes in the production rate, it must be a priority to negotiate takeoff contracts with the manufacturers. If costs are not fixed, they should be determined on reasonable terms so that both the supplier and the client can benefit. Transportation of material as indicated before will be outsourced and the company will concentrate on its core business.

6.6. Qualitative risk analysis

Risk is the measure of the probability and consequence of not achieving a defined project goal (Kerzner, 2001). Risk analysis broadens sensitivity analysis by using probabilities to quantify the likelihood of variations in the variables used to forecast results. All risks are quantified by analysing the probability of occurrence and, if they occur, the seriousness of the consequences they entail. The risk attached to all is high and will interfere with the completion of the task at the planned period and cost. The occurrence of the risks can also sacrifice the project. Risk identification, quantification, measurement and control relevant to this project are summarised below.

A qualitative risk analysis is adopted to identify variables that cannot be accounted for in sensitivity analysis because of the difficulty in estimating them or presenting them numerically (Kerzner, 2001). The table below looks at risk management. This is a proactive action that either prevents the occurrence of the risk or minimises its impact should it not be preventable. Some of the variables are transport costs, water availability, legislation etc. These are all high risk factors that might affect the success of the project.

Exploration and resource and reserve estimation are the vital determinants of whether the material will be worth exploiting. If data collected during this phase is incorrect, it will affect the project when the material produced does not conform to the specifications of the clients. The processing plants will be based on this data; therefore, if it is not correct, the infrastructure will not serve the purpose it was created for.

The next phase will be to apply for the mining permit, and its approval will be supported by the:

a) Prospecting work done;
b) Technical ability of the company;
c) Financial ability to exploit the deposit; and
d) Environmental impact that the project will have on the environment.

However, having taken care of the above, transport is a major issue that the company has no control of. For the past three years, the oil price has been escalating at an alarming rate and this has had an effect on the transport industry. Higher petrol or diesel prices will lead to the overall cost of supplying the material becoming expensive and clients might end up looking for substitutes that are located closer to their factories and are also cheaper than nepheline syenite. Transport costs might cost the company contracts. Unfortunately, in the route between the location of the deposit and the potential client, there is no alternate transport facility such as a railway option. The option of procuring transportation as planned will not minimise the risk. In this option the company will benefit by not managing the fleet as it is not one of its competencies. It must however be noted that transport costs would affect the feldspar producers to a similar extent.

Table 17: Qualitative risk analysis

ITEMS	RISKS	MEASURE-MENT	CONTROL STRATEGY
INTERNAL			
Resource & Reserves base model	• Inaccurate assessment of resources & reserve.	Cost and time.	Competent geological staff
	• Unforeseen geological conditions.	Cost and time.	Contingency for those surprises.
Costs	• Rise in production costs.	Cost increase.	Device ways of minimizing costs.
Quality of technical services	• Labour related issues (contractors).	Performance	Measure through performance appraisals.
EXTERNAL:			
Legislation	• Government legislation- MPRDA.	Time.	Understanding of the protocol.
	• Approval of mining permit	Time.	Provide all necessary information timeously.
Communication	• Unapproved surface developments.	Cost & Time.	Consult affected parties.
Technology	• Technology.	Upgrading costs.	Budget for upgrading to meet industry requirements.
Market Conditions	• Commodity prices.	Cost instability.	Financial viability study considering worst and best cases.
	• Collapse in building industry.	Sales	
	• Cheaper substitutes.	Sales	
Transport	• Higher costs.	Costs of transporting material	Budget for escalating prices & consider other transport options.
Water	• Source	Cost	Option to beneficiate should consider availability of water.
Social	• Community	Compensation costs	Negotiate reasonable access to source of water.
Customer Service	Supplier/customer relationship.	Sales	On-going contact to ensure satisfactory service.

CHAPTER 7

7. CONCLUSIONS AND RECOMMENDATIONS

The Pilanesberg Red Syenite and Bulls Run have higher percentages of nepheline as compared to other nepheline-bearing deposits worldwide. It was established that a detailed investigation on the lithological units is required as it is indicated in the literature that Red Syenite is developed within the white foyaite. This will ensure that long-term contracts are based on the correct geological data and resources and reserves are quantified accurately. The importance of this was indicated by the ceramics manufacturer, where an interest in the production and a willingness to sign a long-term contract were shown should the product fall within prescribed quality standards. However, a major concern from the industry is the continuity of the deposit and the quality. It is recommended that further geological work be undertaken to confirm the resources and reserves estimates of the entire nepheline-bearing deposits in the Pilanesberg outside the area demarcated as a national heritage site.

Samples submitted to glass and ceramics manufacturers triggered an interest in the use of nepheline in ceramics. It was established that glass and ceramics manufacturers have different needs as far as the product they require is concerned. Therefore, in the process of testing, both beneficiated and unbeneficiated samples need to be distributed. As far as composition component is concerned, the deposit complies with the specifications of ceramics manufacturers. The glass manufacturer through its testing procedure established that the unbeneficiated product as represented by samples submitted, did not comply with the production of the kind of glass it dealt in. Major limitations on nepheline being the preferable raw material for these industries are the availability and abundance of competing substitutes such as feldspar. Nepheline syenite deposits are located far from the market, which is at present, Gauteng, but the feldspar producers also suffer from the disadvantage although they have the benefit of railway links.

The following factors have been identified as having a major influence on the viability of the Red Syenite deposit:

a) Chemical composition of nepheline
b) The size of the deposit;
c) Demand for the product;
d) Location of the market;
e) Transport logistics; and
f) Market conditions including commodity price.

The size of the deposits and the capability of the deposit to supply long-term contracts are important. In the case of industrial minerals, production can only be guided by the demand. The industrial minerals industry is also governed by the fact that the production rate cannot exceed the demand. Despite nepheline having obvious advantages over substitutes, the demand for it is still very low. On the basis of the statistics obtained from company A, the project will be profitable, but will battle against the dynamic economic environment if the demand does not escalate. From the DCF, it has been established that profitability will continue even when operating and transport costs have escalated. Profitability will continue even when the selling price and demand of the product has decreased by up to 30%. At a higher discount rate (18%), the NPV will still be positive for both the beneficiated and unbeneficiated product at R24.98 and R10.34 million respectively.

The project is, as could have been expected, most sensitive to changes in capital requirements, production rate and selling price. An increase in both the production rate and the selling price will have a positive outcome on the IRR, NPV and the payback period. A decline in the demand, which will be reflected by the decline in the production rate, will reduce the IRR and NPV. The payback period will increase, thus lengthening the payback period of the loan. In the discounted cashflow model, transport and operating costs have a small effect; however, the combination of these parameters can have a significant effect on the viability of the project.

Two scenarios were considered during this investigation namely the production of beneficiated and unbeneficiated raw material product aimed at the glass and ceramics industry. Both scenarios have shown to be financially viable and robust in terms of the input parameters tested in sensitivity analyses. The following aspects should be considered in a strategic comparison of the two scenarios.

Table 18: Base case comparison of the two scenarios investigated (discount rate 14%)

FINANCIAL CRITERION	SCENARIO 1	SCENARIO2
NPV	R20.30 million	R9.21 million
IRR	66%	57%
Pay back period	23.8	25.5
Maximum cash exposure	R1.66 million	R1.10 million

From the comparison it could be concluded that the only aspect in favour of scenario 2 is the fact that the maximum cash flow exposure is 34% less than in scenario 1. This is however overshadowed by the additional shareholder value offered by scenario 1. Of greater importance is the other aspects not considered in the DCF model.

a) Scenario 2 is dependent on a single buyer of its product. This could however be negated by long-term off-take agreements and possible sharing in financial risk. Scenario 2 is also more sensitive to a drop in commodity price than scenario 2.
b) Scenario 1 may only be successful if the barriers in the South African glass manufacturing industry can be overcome and nepheline syenite is accepted as a replacement of feldspar. This could come about if the feldspar producers could not cope with the demands of the growing industry. Scenario 1 is clearly less sensitive to adverse conditions and should be seen as the preferred option for long-term.

It is recommended that a hybrid scenario be considered where the first phase of the project resemble scenario 2 and the second phase which would be self funded an expansion of the project to include the beneficiation plant envisaged in scenario 1. The second phase would be triggered once the operation has proven itself in terms of its ability to produce a homogeneous product consistently and adequate pilot plant tests were done to justify the glass manufacturers to convert capacity or create new capacity based on nepheline syenite raw material.

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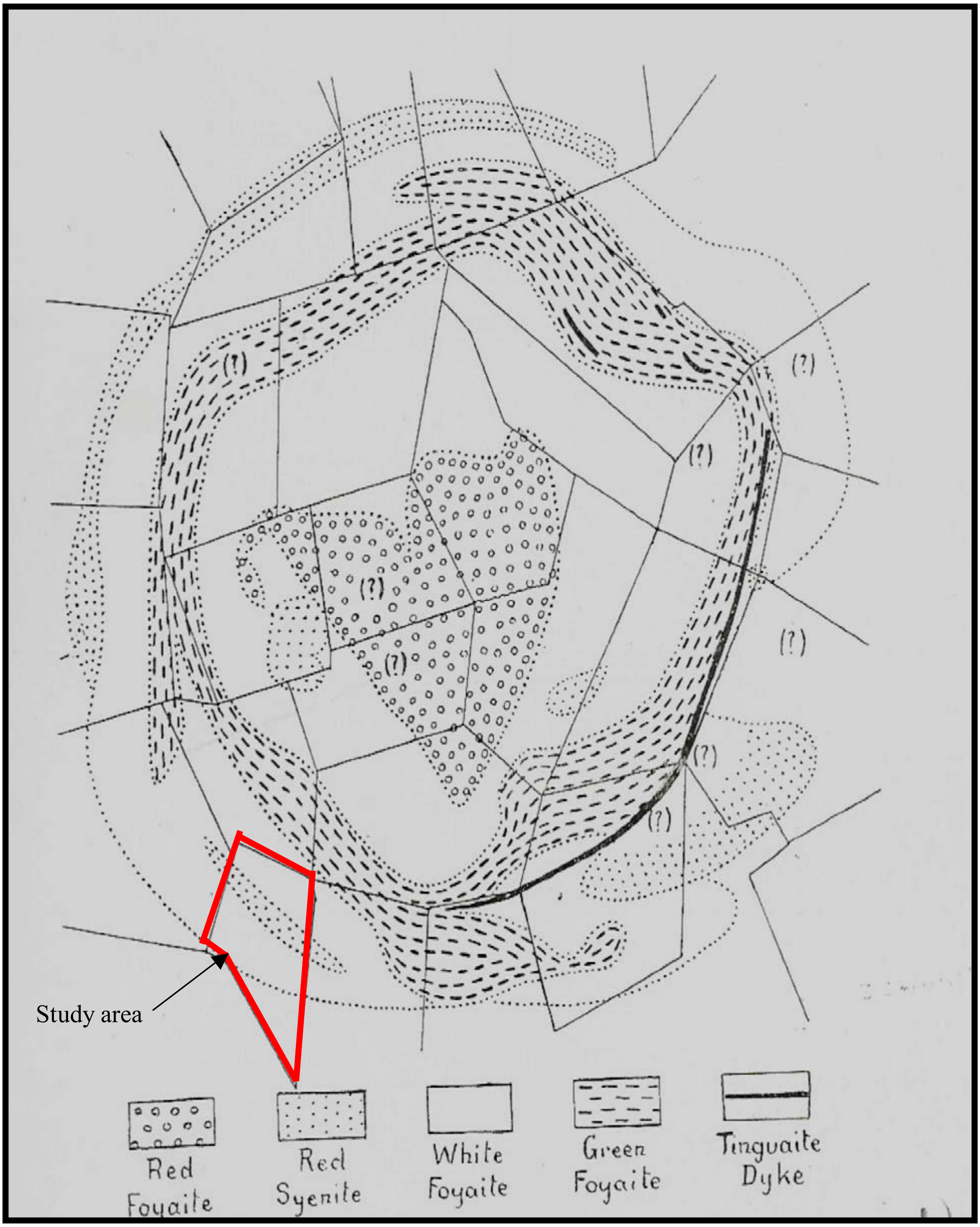
9. APPENDICES

A - Geological plan of the Pilanesberg Complex by Shand (1923)
B – Classification of White Foyaite by Retief (1963)
C - Detailed marketing report
D - The extent of the Heritage Park in relation to Zandrivierspoort 210 JP

Appendix A

Geological plans of the Pilanesberg Complex by Shand (1932)



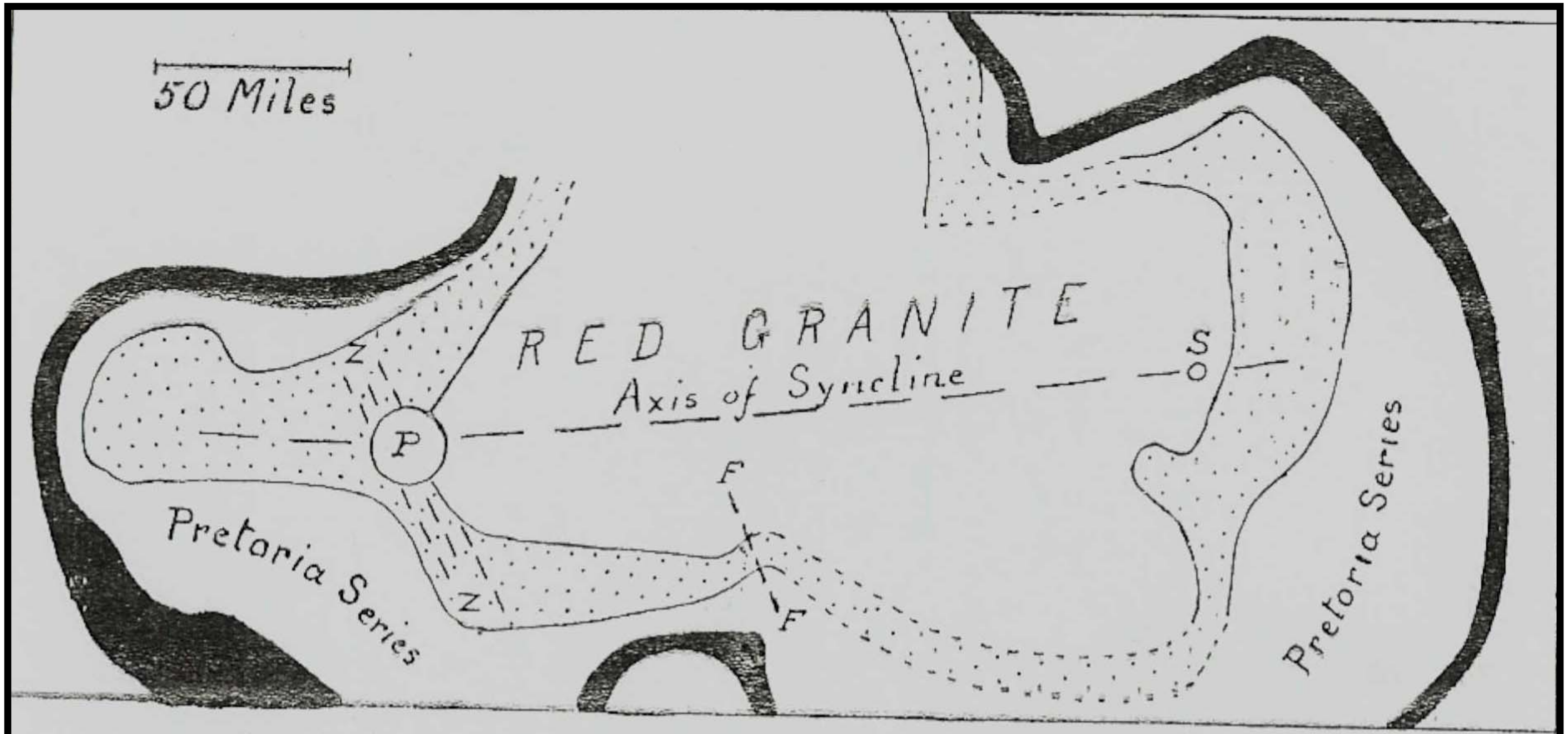


FIG. 1.—GENERALISED MAP OF THE BUSHVELD SYNCLINE, SHOWING THE POSITIONS OF THE MAIN ALKALINE INTRUSIONS.

P = Pilansberg.
S = Sekukuniland foyaite stock.
FF = Franspoort line.
ZZ = Zone of dykes trending through Pilansberg.
Stippled area, norite.
Black, dolomite,

Appendix B

Type	Texture	Feldspar	Nepheline	Pyroxene & Amphibole	Biotite & Iron ore	Zeolites, Cancrinite & Sodaltie	Accessory Minerals	Locality
CENTRAL	Medium grained	K-feldspar	Sub- to euhedral, equant to elongated	Anhedral to euhedral grains	Secondary	Alcanite, natrolite, cancrinite, sodalite	Sphene, zircon	First ring
SOUTHERN	Coarse to medium grained	Large microcline-microperthite laths	Anhedral to euhedral grains	Aegirine-augite dominant	Abundant	Alcanite, natrolite, cancrinite, minor sodalite	Sphene, eucolite	Second ring
MATOOSTER	Coarse to medium grained	Perthite	Anhedral to euhedral grains	Aegirine-augite	Secindary	Alcanite, natrolite, cancrinite, sodalite	Minor sphene, aenigmatite, lovschorrite	Outermost ring
HELL	Medium grained	Microcline	Anhedral to euhedral grains	Aegirine-augite	Minor	Alcanite, natrolite, cancrinite, sodalite	Minor sphene, eucolite	Southern part of Leeuwfontein
DOORNHOEK	Medium grained	Microcline, microperthite, plagioclase	Subhedral to euhedral grains	Aegirine	Secondary	Minor	Minor sphene, eucolite	Central part of Doornhoek
POIKILITIC	Variable	Large oikocrysts	Rounded to euhedral enclosed by pyroxene & feldspar	Subordinate acmite	Minor	Natrolite, cancrinite, sodalite	Minor sphene, aenigmatite, pectolite	Western part of Doornhoek

Appendix C

Detailed market investigation responses

Company A gave the following report after testing the raw nepheline syenite in its system. Quote "We have tested your material and it closely matches the one we are currently using. At this stage we feed close to 39 tons a day and approximately 1120 a month. Please let us know how close and at what cost you can simulate the above distribution. Lab Manager". Further correspondence supported the above- "We find that the material will likely work on our factory. We need to know the following:

a) Proposed price for the product (R/ton) crushed to -13mm or smaller
b) When will the product be available (as soon as possible)
c) Quantity that would be stockpiled (should the product be tested successfully in a production trial, we would consider a 5 – 10 years stockpile, although we would have to put in certain quality and market performance criteria)."

Company B, which is a glass manufacturer, reported that the material is not suitable for the glass it manufactures. It also highlighted that if it wants material it will have to be beneficiated from the site. It does not have facilities to process the material at the factory.

From communicating with several potential users, it was concluded that most companies are not willing to substitute what they are using with nepheline, despite its advantages. Company B transports its raw material from Thabazimbi; the material under consideration is from Pilanesberg. Besides the nepheline source being closer to company A, it offers more benefits. There was a concern raised about consistency in quality and supply and transport costs. Out of nine companies, only one in Gauteng is using nepheline syenite and is keen to sign a contact for a five to ten years stockpile should the material successfully test in the production trial as mentioned above.

Appendix D

The extent of the Heritage Park in relation to Zandrivierspoort 210 JP