

BENTONITE, PYROPHYLLITE AND TALC IN THE REPUBLIC OF SOUTH AFRICA 2004

DIRECTORATE: MINERAL ECONOMICS



A Pyrophyllite Mine



the dme

Department:
Minerals and Energy
REPUBLIC OF SOUTH AFRICA

**BENTONITE, PYROPHYLLITE AND TALC
IN THE REPUBLIC OF SOUTH AFRICA
2004**

DIRECTORATE: MINERAL ECONOMICS

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Bentonite

Executive Summary

Bentonite is a colloidal, aluminosilicate clay derived from weathered volcanic ash and largely composed of montmorillonite. Bentonite consists of aggregates of flat platelets that have a high specific surface area, high plasticity, expand when wet; and are inert and non-toxic. Uses of bentonite include thickening and/ or suspension agents in drilling muds, sealants, paint pigments, clarifying agents and pesticide carriers; as a binder in metallurgical uses, and as an absorbent in cat litter applications.

Excellent recovery rates, extensive mineral reserves and LOM plans, selective and campaign mining, minimal overburden, consistent product specs, Na-acid activation, modern / pioneering technologies, good R & D, continuous market analysis and exemplary compliance (safety & environmental) epitomize the bentonite industry.

The location of bentonite deposits and depots to manufacturers and end-user markets are crucial – e.g. the Cape Bentonite Mine is about 1 600km away from the majority of its customers, however, its depots are located centrally to improve turnaround times and reduce transport costs. Most customers have 3 months stock on-site too.

There is much competition [locally] in both high- and low-end product ranges. Imported, high-value, high-purity synthetic and nano-fine grades fetch much higher prices, costing between 5-25 times more than local products.

Over the last 15 years, the bentonite industry and its associated markets have been characterized by strong growth and product diversity. Major markets are the ferrochrome, foundry, drilling muds, civil and oil bleaching applications, which account for 91% of total sales.

Growth markets include civil/ environmental (particularly import replacements, water retention and treatment), medicinal, aquamarine, nanoplastics, fibre technologies, pulp and paper manufacturing and composite material manufacturing that includes TiO₂ composites (dye-removal), copper citrate composites (wine-clarifying) and bentonite sandwiches (civil applications) that will ensure real sales growth over the next 5-10 years. The two largest deterrents to significant real growth in niche markets are the "consumer mindset and ignorance".

Over the last 3 years, producers have shifted their focus to the finished, tailored product – this includes quality checks and customer support. Value addition (i.e. Na-addition, fine sizing, classifying and blending) is a necessity – all producers are currently looking at technologies to improve fineness and reduce particle size distribution.

Bentonite recycling initiatives include the recovery of spent foundry sands for use in ceramic and tile manufacture; and the use of lightweight aggregate (mix of fly ash and bentonite) in construction, although the latter has proved unsuccessful.

Transport mediums for bentonite products have shifted strongly towards road transport in the last 7 years. Inter-product substitutes; other pelletising clays; improved efficiencies (marginal) in green sand casting, and new casting technologies requiring lower capital expenditure and less bentonite per unit cast are major threats.

The consistency, quality and swelling properties of South African bentonites are favourable for exports, although the location of local producers in terms of world markets and the low Rand- dollar exchange rate makes export initiatives uneconomical at present.

However, exports to the Middle East, Far East, South American and Europe as well as the SADC countries can be expected to grow by at least 9 percent year-on-year, depending on foreign exchange rates. Should the Rand reach the R7,50/\$ mark, this may open up large export markets for drilling muds, civil uses and micronised products. Strong growth of 6-8% is expected in all major bentonite markets for the next 4 years, with a tapering off over the following years.

The recently introduced MPRD Act has forced many role players to implement and adhere to stringent health, safety and environmental codes. Renewed threats of silicosis remain a contentious issue in the bentonite industry.

Black economic empowerment initiatives are set to increase significantly in the next 5 years – particularly around pit operations, material handling, logistical/ transport services and partnerships/ joint ventures. Ecce Holdings already has an effective 26% BEE shareholding.

Importance

Share of industrial minerals sector '04

Production	0.2%
Revenue	0.9%
Export Value	0.2%
Employment	0.6%
Remuneration	0.7%

Fundamentals

Key Indicators '04

Market Cap. (R Mil.)	400
Reserve Base (Mt)	8
Production (kt)	100
Total Sales (kt)	90
Total Sales (R Mill.)	178
Exports (kt)	<10
Average LOM	40
Growth (y-o-y), 2007	5-6%
Growth (y-o-y), 2010	4-5%

Markets '03

Local bentonite (115 kt) *

1	Ferrochrome	34.1%
2	Foundry sand	31.6%
3	Oil bleaching	11.5%
4	Civil applic.	8.1%
5	Drilling muds	5.0%
6	Other	9.7%

Niche / Growth markets

Aquamarine
Cement additives
Dye-removal
Fibre technology
Nano-plastics
Pharmaceuticals
Polypropylene composites
Pulp & paper manufacture
Water retention / treatment
Wine clarifying

* Includes imports

Talc & Pyrophyllite

Executive Summary

Talc, a hydrated magnesium silicate, can be found in sheet-like masses, be foliated or have a scaly appearance, and has perfect basal cleavage that allows it to split into wavy, flexible, non-elastic flakes. **Pyrophyllite** is a hydrous aluminium silicate with a structure similar to talc, although it's slightly harder and more refractory.

A host of optical, refractory, chemical and physical properties determine the markets to which talc and pyrophyllite are suited. Local pyrophyllite deposits are internationally acclaimed as being "A-grade" and command a high price internationally, whilst local talc is of low-grade and used mostly as a filler in paint, resins, soaps and adhesives.

High-grade deposits, good recovery rates, extensive mineral reserves and LOM plans, selective and advanced mining techniques, minimal over-burden, cutting-edge technologies, excellent internationally-accepted products, rapid market-share growth, very successful R & D and good customer relations epitomize the pyrophyllite industry.

Low to medium-grade deposits, remotely located mines, good recovery rates, extensive mineral reserves and LOM plans, selective mining, minimal over-burden, high transport costs, consistent low-grit products, competitively-priced cheap imports, large market potential (kaolin substitution), continuous R & D and good customer relations epitomize the talc industry.

All local talc mines are located at least 400km from their nearest markets. On-site plants carry out between 30-60% of mineral processing/beneficiation; whilst centrally located plants (near major markets and distribution centres) carry out 2nd and 3rd stage crushing and value addition. Transport costs account for up to 65% of sale price. In the pyrophyllite industry, location is not important – transport comprises about 25-30% of the final product price, however with high-quality finished products, transport costs are less than 1%.

Over the last 5-10 years, producers have shifted their focus to the finished, tailored product – this includes quality assurance, packaging, expedient delivery and customer support. Value addition (i.e. fine sizing, higher purity, reconstituted and fully-manufactured products) has become an absolute priority. Transport mediums for alumino-silicate products have shifted strongly towards road trans-

port in the last 7 years.

Over the last 10 years, the talc industry has stagnated, partly because of other fillers such as GCC and calcined kaolin taking market share (both directly and indirectly). Pyrophyllite sales have been buoyant as the creation of new markets; new partnerships and successful R & D have opened up tremendous scope for the medium and long-term.

Major markets for talc and pyrophyllite are paint, paper, synthetic diamond manufacture, resin filler and refractory applications, which account for 86% of total sales. Niche/ growth markets for pyrophyllite and talc include specific refractories, wear chute linings, special paints, chromic acid pots, wire drawing, new crucible products, import replacement in the paper industry, personal healthcare, brake linings, white cements and other civil applications.

In the high-value pyrophyllite market, international competition is intense. These markets include refractories, synthetic diamond manufacture, kiln furniture and wear-linings. Product differentiation, reputation and quality, price, consistency, yield and tolerance factors, exchange rate fluctuations and ISO compliancy are crucial success factors in this industry. Pyrophyllite sales are also governed by global changes in macro-economies (industrial upturns/ downturns), international regulations and well-marketed cheaper substitutes.

Current and future threats to the pyrophyllite industry have forced producers to manufacture finished crucibles and even launch their own synthetic diamond manufacturing processes – an example of perfect value-addition.

Expected growth in the talc and pyrophyllite industry has been forecast at 5- 6% (higher than the national economy's), however pyrophyllite exports may grow at significantly higher rates of 7-9% y-o-y.

The recently introduced MPRD Act has forced many role players to implement and adhere to stringent health, safety and environmental measures.

Black economic empowerment initiatives are set to increase significantly in the next few years – particularly around pit operations, material handling, logistical/ transport services and partnerships/ joint ventures. BEE partnerships are already in place with parent companies in the pyrophyllite industry.

Importance

Share of industrial minerals sector '03

Production	0.1%
Revenue	0.7%
Export Value	0.9%
Employment	1.2%
Remuneration	0.5%

Fundamentals

Key Indicators '04

Market Cap. (R Mil.)	500
Reserve Base (Mt)	36
Production (kt)	21
Yield (%)	85
Total Sales (kt)	26
Total Sales (R Mill.)	41
Exports (kt)	<1
Average LOM	70
Average mine age	47
Growth (y-o-y), 2007	5-6%
Growth (y-o-y), 2010	3-4%

Markets '03

Pyroph. & Talc (32 kt)

1	Paint	44.0%
2	Paper	25.4%
3	Crucibles*	10.7%
4	Resin filler	4.4%
5	Refractories	1.9%
6	Traders	3.7%
7	Other	10.4%

* Used in synthetic diamond manufacturing

Niche / Growth markets

Bullet-proof vests
Cement & other fillers
Nano-paints & plastics
Paper & pulp process
Personal Healthcare
Pharmaceuticals
Specific refractories

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Abbreviations

Å	Angstrom (1×10^{-8} metres)
AAB	Acid-activated bentonites
ADTs	Articulated dump trucks
BEE	Black Economic Empowerment
Bento.	Bentonite
BGS	British Geological Society
DME	Department of Minerals and Energy
EMP	Environmental Management Programme
FELs	Front-end loaders
FOB	Free on board
FOR	Free on rail
GCC(s)	Ground calcium carbonate(s)
GCL(s)	Geosynthetic clay liner(s)
kbar	1000 bar
kt	Kiloton (1000 tons)
L	Litre
LOI	Loss on ignition
LOM	Life of Mine
MPRD Act	Mineral & Petroleum Resources Development Act
mont.	Montmorillonite
Mt	Megaton (1 000 000 tons)
m ²	Square metres
na	Not available
NOSA	National Occupational Safety Association
nm	Nanometre (1×10^{-9} metres)
OFS	Orange Free State
p.a.	Per annum
PCC	Precipitated calcium carbonate
PROD.	Production
psi	Pascal per inch ²
Pyroph.	Pyrophyllite
R/t	Rands per ton (in ZAR)
R&D	Research and development
S.A.	South Africa
SARS	South African Revenue Service
Spec	Specifications
t	Tons (1 000 kg)
TiO ₂	Titanium Dioxide
µm	Micron (1×10^{-6} metres)
USA	United States of America
y-o-y	Year-on-year
°C	Degrees Celsius
#	Mesh

Definitions

Acid-activation is a process whereby all cations (Ca^{++} , Mg^{++} , Al^{+++}) are replaced by H^+ through the addition of H_2SO_4 or HCl ; the molecular structure is modified in the process.

Beneficiation is the removal of gangue minerals from ore via physical or chemical means.

Bentonite is a clay material consisting essentially of the *smectite* clay mineral, montmorillonite.

Brownfield projects include expansions and exploration done on site or in close proximity to current infrastructure.

Excipients are inert or slightly active substances that act as a vehicle or medium of administration for medicinal agents.

Greenfield projects include exploration and infrastructural projects located some distance away from the mine and/or plant perimeter.

Outokumpu process – a process whereby chrome ore fines and low-grade chromitic ores can be used to produce ferrochrome. Bentonite is the standard binder for pelletising in this process. Advantages of this process include low energy consumption.

Smectite is a group name for clay minerals with a layered structure that possess swelling properties and high cation-exchange capacities. Four properties that make smectite unique and commercially important are: a) particle size, b) -shape, c) -charge and d) cationic exchange.

Soda ash activation is a process whereby larger cations (Ca^{++} , Mg^{++}) are replaced by smaller atoms (Na^+) by the addition of soda ash.

Spathic – Minerals exhibiting good cleavage planes, foliation and/ or distinct lamella.

Thixotropy refers to the ability of a mineral or solid to become fluid if stirred and thicken when agitation ceases.

Whiteware includes merchandise such as fridges, toasters, stoves, etc.

Notes

Average Price is the average of the sum of several prices and is not based on total sales ÷ total volumes. Any other **price** is: total sales ÷ total volumes.

In the text, **pyrophyllite**, **wonderstone** and **roseki** are treated as one and the same mineral, namely pyrophyllite.

In the text, **1 ton** is equivalent to **1 metric ton**. The terms are used interchangeably.

In the text, **foundry sands**, **foundry casting** and **foundry industry** all pertain to the same consumer market.

A. Bentonite

1. Introduction

Bentonite – Bentonite is named after the Benton Shale Formation in Wyoming, USA, in which the first bentonite mine (1897) was located. The Benton Shale drew its name from Fort Benton, Montana, USA.

Fullers Earth – An Old English term derived from the practice of textile workers (or fullers) who cleaned raw wool by kneading it in a clay-water mixture that adsorbed oil, dirt and contaminants from the fibres.

Montmorillonite – A clay assemblage named after the town Montmorillon, Vienne, France where it was first quarried.

Much confusion exists around the commercial name “bentonite”. Table 1 is an attempt to distinguish between Na and Ca-based bentonites/ montmorillonites and Fuller’s earth, in the South African context.

Table 1: Commercial bentonite and attapulgite terminology

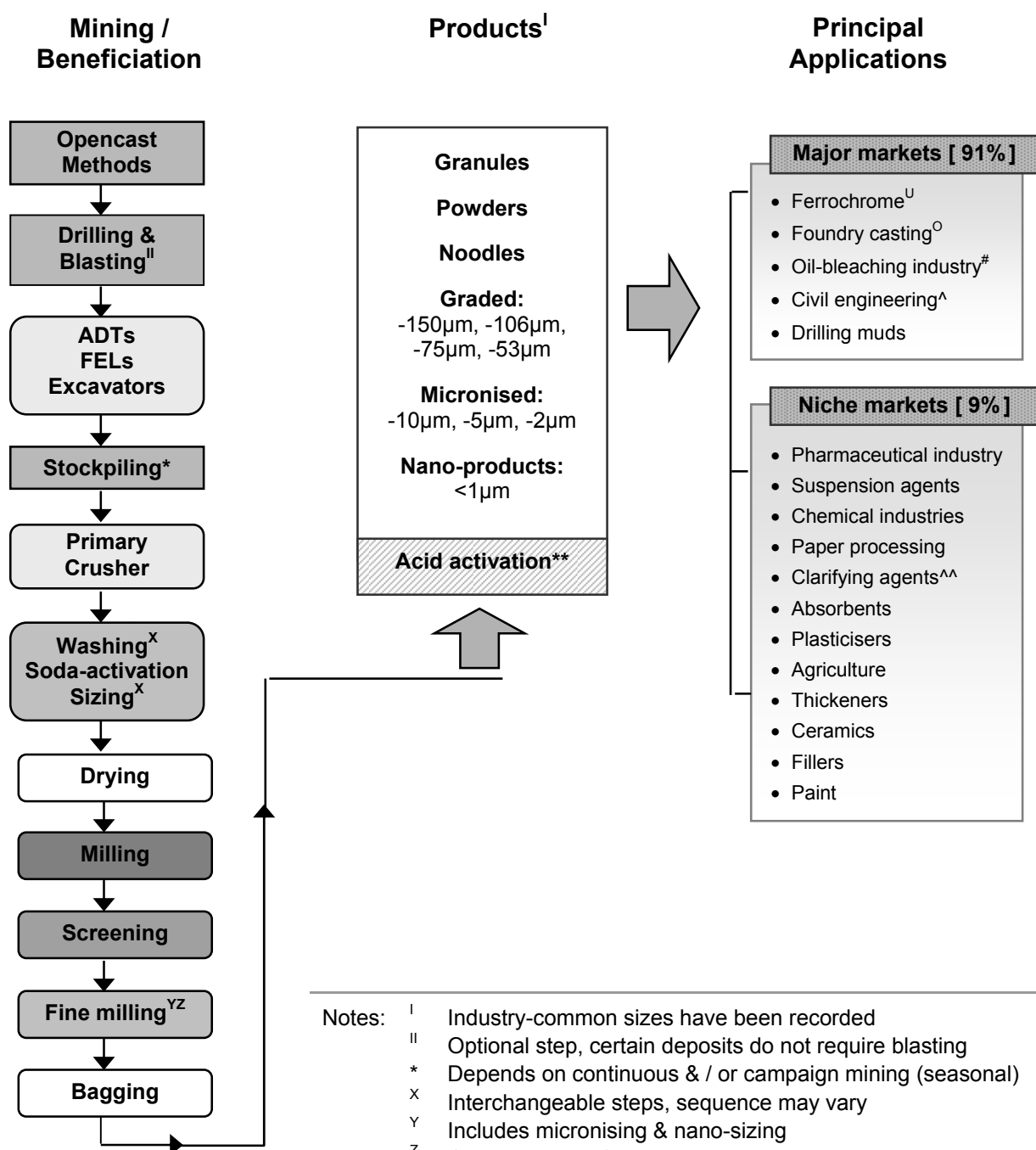
Mineral name	SA equivalent	UK equivalent	USA equivalent
Bentonite	Na & Ca mont.	Sodium mont.	Na & Ca mont.
Sodium (Na) bentonite	Sodium (Na) bentonite	Bentonite	Wyoming bentonite
Calcium (Ca) bentonite	Calcium (Ca) bentonite	Fuller’s earth	Southern bentonite
Fuller’s earth	Attapulgite / Palygorskite	Fuller’s earth	All bleaching clays: attapulgite, sepiolite

Bentonite is a colloidal, alumino-silicate clay derived from weathered volcanic ash and largely composed of montmorillonite. It consists of an aggregates of flat platelets, has a high specific surface area, high plasticity, expands when wet; and is commonly used as a thickening and/or suspension agent in drilling muds, sealants, paint pigments, clarifying agents, pesticide carriers and is inert and non-toxic (see *Addendum 1*).

More than 75% of bentonite consumed in South Africa is produced by two opencast mines – Cape Bentonite (owned by Ecce Holdings) near Heidelberg, Western Cape and the Ocean Bentonite mine (owned by G & W Base & Industrial Minerals) near Koppies, Free State. The Plettenberg Bay mine (part of the G & W Base group) near Knysna (Western Cape) officially closed two years ago and is being rehabilitated. Reserves of bentonite are in excess of 8 Mt although not all of it is considered to be economically mineable. Additional brown- and greenfield exploration would enlarge current reserves two-fold. Three medium/ high-grade deposits have been discovered in the last 15 years, although all three have unique problems and constraints.

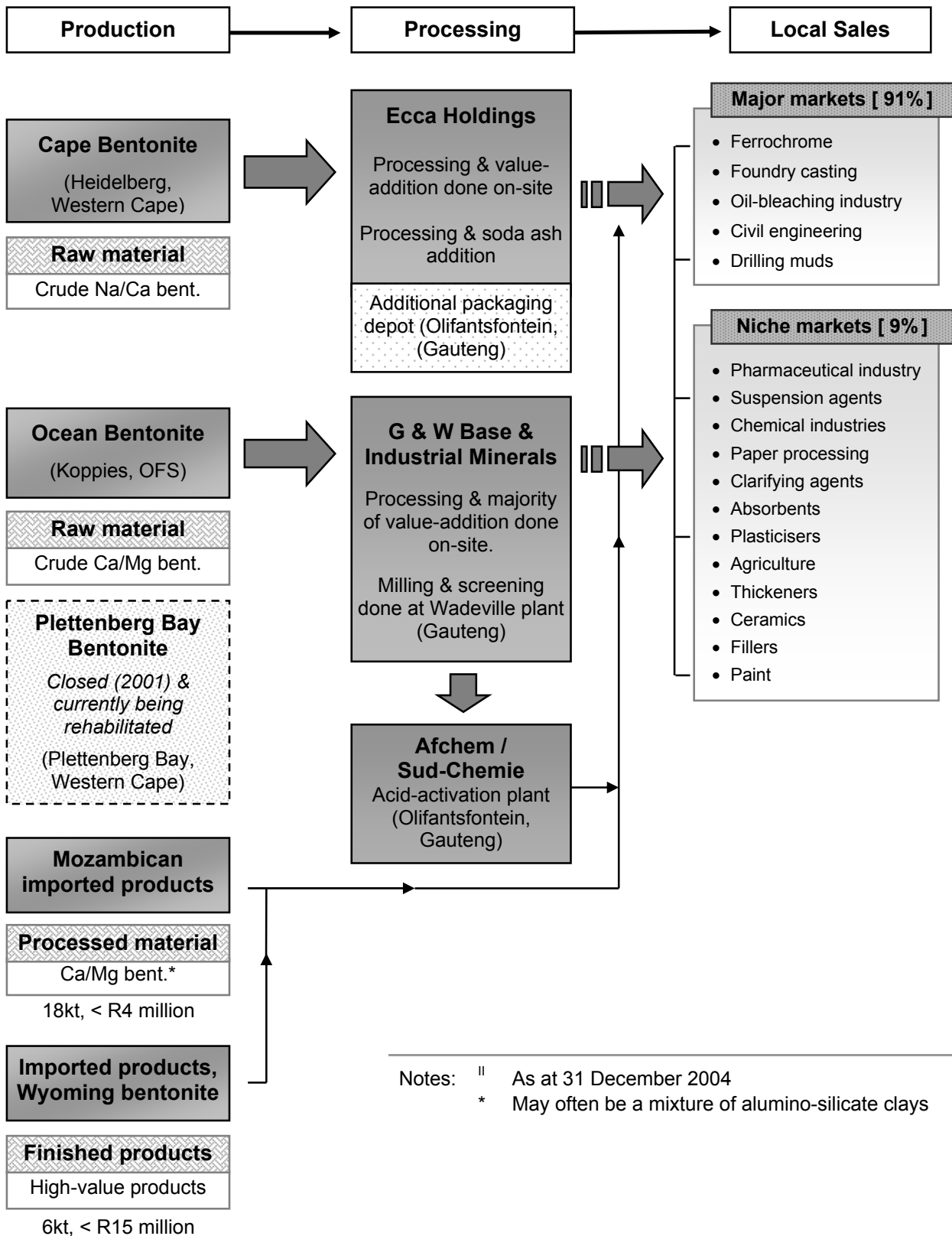
Value-addition of bentonite includes soda ash activation, drying, milling, granulation and fine milling. Ca-bentonites are best suited for acid-activation (exclusively H⁺ activation), which enhances surface area. Very little blending of calcium and sodium bentonites is done in South Africa. Substitutes for bentonite do exist but use of alternative materials depends on cost, availability and performance. South Africa’s primary markets, in descending order of magnitude, are chrome ore pelletising, foundry casting, oil-bleaching, drilling muds and civil applications.

2. Industry Flowchart



- Notes:
- ^I Industry-common sizes have been recorded
 - ^{II} Optional step, certain deposits do not require blasting
 - ^{*} Depends on continuous & / or campaign mining (seasonal)
 - ^X Interchangeable steps, sequence may vary
 - ^Y Includes micronising & nano-sizing
 - ^Z Optional step, often done independently at other plants
 - ^{**} Ca-bent. specifically used in oil bleaching, 60% AAB exported
 - ^U Bentonite used as a binder / pelletising agent
 - ^O Bentonite used as a binder
 - [#] Clarifying agent
 - [^] Used in dam sealing, grouting, piling and mining applications
 - ^{^^} Used in beverages, edible and mineral oils

3. Industry and Company Structure^{II}

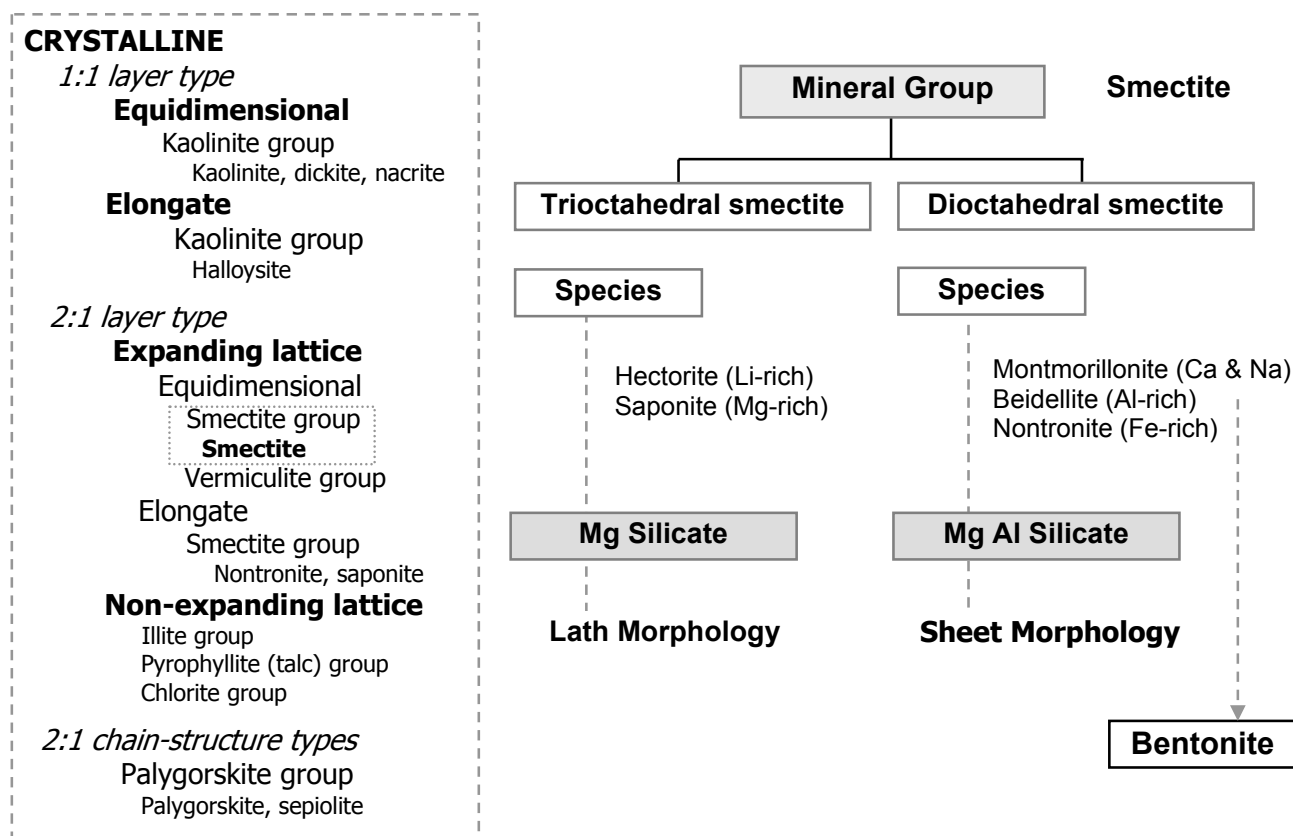


4. Raw Material

4.1 Bentonite Nomenclature / Classification

Bentonite is a clay material consisting essentially of the smectite clay mineral, montmorillonite. Smectites are divided into 2 groups, *dioctahedral* and *trioctahedral smectites*. These grouping can be further subdivided into several species (Diagram 1 and Addendum 1).

Diagram 1: Bentonite Nomenclature and Classification



4.2 Bentonite Characteristics

Montmorillonite has the following chemical formula: $M(Al,Fe,Mg)_4(AlSi)_8O_{20}(OH)_4 \cdot nH_2O$, where

- a) the relative amounts of Al, Fe and Mg are not fixed
- b) M represents the exchangeable cations Ca, Mg, Na
- c) nH_2O is the hygroscopic water content (Diagram 2)

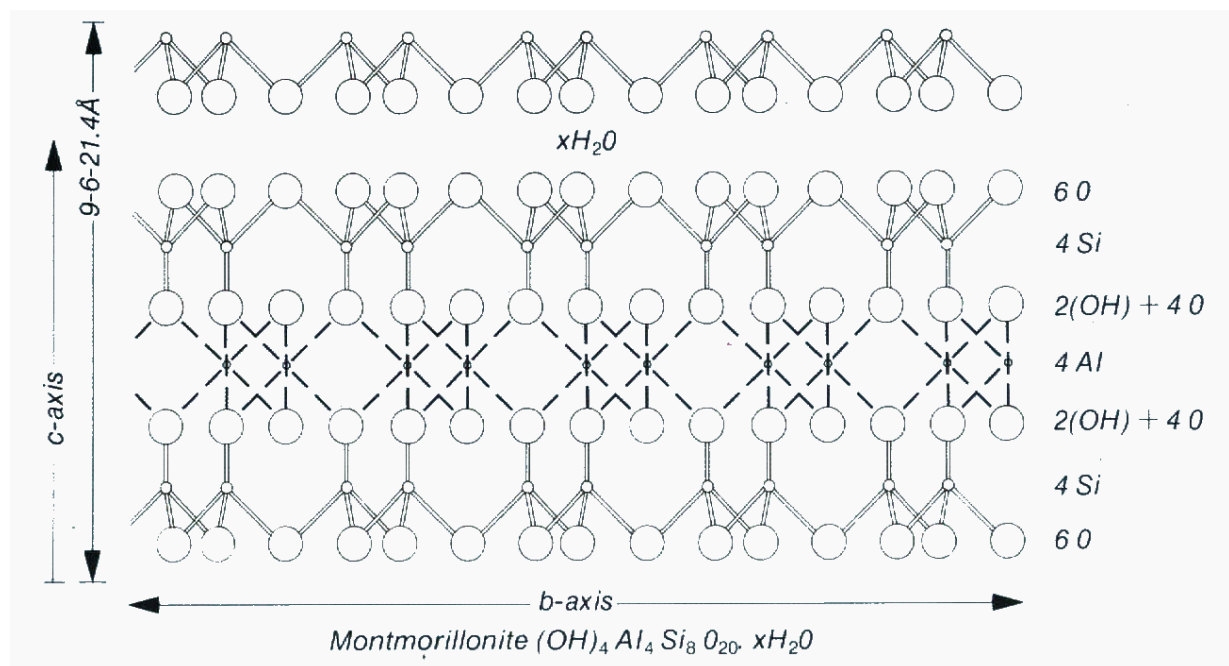
Montmorillonite crystals have a flat, thin sheet morphology. They are irregular in overall shape and can be up to 1,000 nm (10,000 Angstroms) in the largest dimension. However, a side view of the crystal reveals a uniform size of 0.92 nm thickness. The result of this morphology is an extremely large surface area of about 800m²/ gram.

Quartz is normally the major non-clay mineral in most bentonites, but trace amounts of feldspars, biotite, muscovite, pyrites, calcite, and other minerals can be found in it. The average smectite to other minerals ratio is typically 75:25. The two types of bentonite, calcium and sodium bentonites are three-layered aluminosilicate clays with water molecules between their layers.

The principal difference between the two bentonites relates to the composition of the inter-layer cation (mostly Na and Ca). When wetted, both types of bentonite will increase their volume and swell, with sodium bentonite expanding 15-20 times its volume, and calcium bentonite increasing 0-5 times in volume. Sodium bentonite expands to a greater degree because the Na-cation can hydrolyse more than the Ca cation. This swelling property gives bentonite excellent, cohesion, binding, thickening, and sealing properties. Dry bentonite has a range of colours, from medium grey to white, with colours such as pale brown, yellow-grey and brown-grey also common.

Bentonite is valued for its sorptive properties, catalytic action, bonding power and cation exchangeability, the latter enabling calcium bentonite to be easily converted to sodium bentonite, which in turn exhibits thixotropy. This property is present when the main exchangeable cation in the montmorillonite is sodium. Addition of water to the bentonite causes the platy particles of the clay to part (swell). The plates have negative charges on the surface and positive charges on the edges. In a suspension with a low solid content, the particles orientate themselves negative to positive and form a gel. If the solution is disturbed, e.g. stirred, the electrical bonds are broken and the mix becomes fluid-like.

Diagram 2: Montmorillonite (Ca & Na bentonite) structure



Notes:

O	= Oxygen atom
Al	= Aluminium atom
Si	= Silicon atom
OH	= Hydroxide molecule
H ₂ O	= Water molecule

4.3 Acid-Activated Bentonite

Acid-activation enhances properties already present in the bentonite by changing its chemical and physical properties without destroying the clay's layered structure. By activating bentonite with inorganic acids such as H_2SO_4 or HCl , the following occurs:

The outer calcium ions are replaced by H^+ ions, which form what is referred to as an H-bentonite. In the course of further activation, the individual layers are attacked directly by the mineral acid [H_2SO_4], and various ions, such as aluminium, iron, calcium and magnesium are released from the lattice. The acid also dissolves impurities such as calcite. The acid accordingly penetrates from the crystal surface deeper and deeper into the crystal structure of the individual layers, which causes the inner surface of these crystal platelets to increase in size, and active acid centres to be formed.

During the acid decomposition, an optimum degree of activation is reached. Further chemical treatment reduces the activity again, and finally leads to the dissolution of the crystal and the formation of silicic acid. Physically, the edges of the clay platelets open up, surface pore diameters increase and the surface area increases.

The activation of the crude bentonite provides the bleaching earths with the following properties:

- ▶ Protons replace the outer calcium ions, which results in a high ion exchange capability and special catalytic properties. The product has properties similar to that of a solid mineral acid.
- ▶ A large number of acid sites are formed in the montmorillonite crystals, due to the removal of metal ions from the crystal lattice and the formation of silanol groups and amorphous silicic acid, which is bound to the montmorillonite crystal.
- ▶ Through the development of a large internal surface, the original small surface area of the raw material is increased many times over. Depending on the type of bleaching earth, this ranges between 120 and 300 m^2/g , while the crude clay, for comparison, features some 70 m^2/g .

By varying the amount of acid concentration, temperature and activation time, the overall efficiency, adsorptive/ decolouring capacity, acid properties, catalytic properties and ion exchange capacity of the bentonite is affected. The particle size also plays a role in the product's performance, e.g. finer clays provide better bleaching and decolouring properties due to larger surface areas. However, particle size has to be weighed against efficient filtration, filtration time and oil retention in the clay. In South Africa, only H_2SO_4 is used as the activation agent.

Acid-activated clays are essentially used in the refining of edible oils and fats, industrial lubricants and waxes. They are also used in toilet and cosmetic soaps as well as in a variety of specialist applications such as in paints and varnishes. Refining of edible oils and fats involves the removal of impurities such as phosphatides, fatty acids, gums and trace metals. It also decolourises and deodorises the final product. Acid-activated bentonite is also used to reclaim industrial lubricants. It removes water, residual additives, degradation products, unburnt fuel and other contaminants. The resulting oil is then used as a base blending stock.

Example: Based on tests done by the Xi'an University of Architecture and Technology (China); under optimum activation conditions, the decolouring capacity of the specified bentonite improved from about 16 for the raw material to 210.5 for the activated bentonite. Further, it was found that during the activation process significant chemical changes do occur – the removal or dissolving of octahedral cations. The decolouring capacity of the activated product reaches its maximum value when the total dissolving rate of the octahedral cations reaches about 30%.

4.4 Geological Setting and Occurrences

It is generally accepted that bentonite is formed from volcanic ash and glass that has accumulated in beds, mainly during the Tertiary or Cretaceous Ages. Current research suggests that bentonite may be an alteration product of other igneous rock types too. Bentonite has also been linked to Triassic and Jurassic formations, but most commercial-grade deposits are associated with the Tertiary and Cretaceous Age.

Bentonite is largely found in marine beds, so, it is assumed that the metamorphosis of this ash and sediment into bentonite is favoured in saline waters. After the settling and deposition of volcanic ashfalls, montmorillonite forms, due to the reactive nature of the ash. Eventually, the deposition of silt and mud on top of these ash/ sediment beds compacts the material into clay beds. Today, bentonite is found mainly in lens-shaped, bedded bodies along with gravel, silt, sand, and limestone. Economically viable deposits are generally surficial, with a maximum overburden of 20 metres.

Deposits of relatively pure bentonite occur in South Africa at Koppies in the Free State and in the Heidelberg and Plettenberg Bay districts of the Western Cape (Diagram 3). Impure deposits are found at Mkuze in Northern Kwazulu Natal and at Wodehouse (near Jamestown, Eastern Cape). All these deposits formed by the alteration of volcanic material.

The bentonite deposits in the Koppies district in the Free State are flat-lying and lenticular in shape and occur underneath and within Ecca shales. The deposit is of volcanic ash origin, with *in situ* alteration of layered volcanic ash. The exchangeable cations in this deposit are essentially Ca^{++} and Mg^{++} .

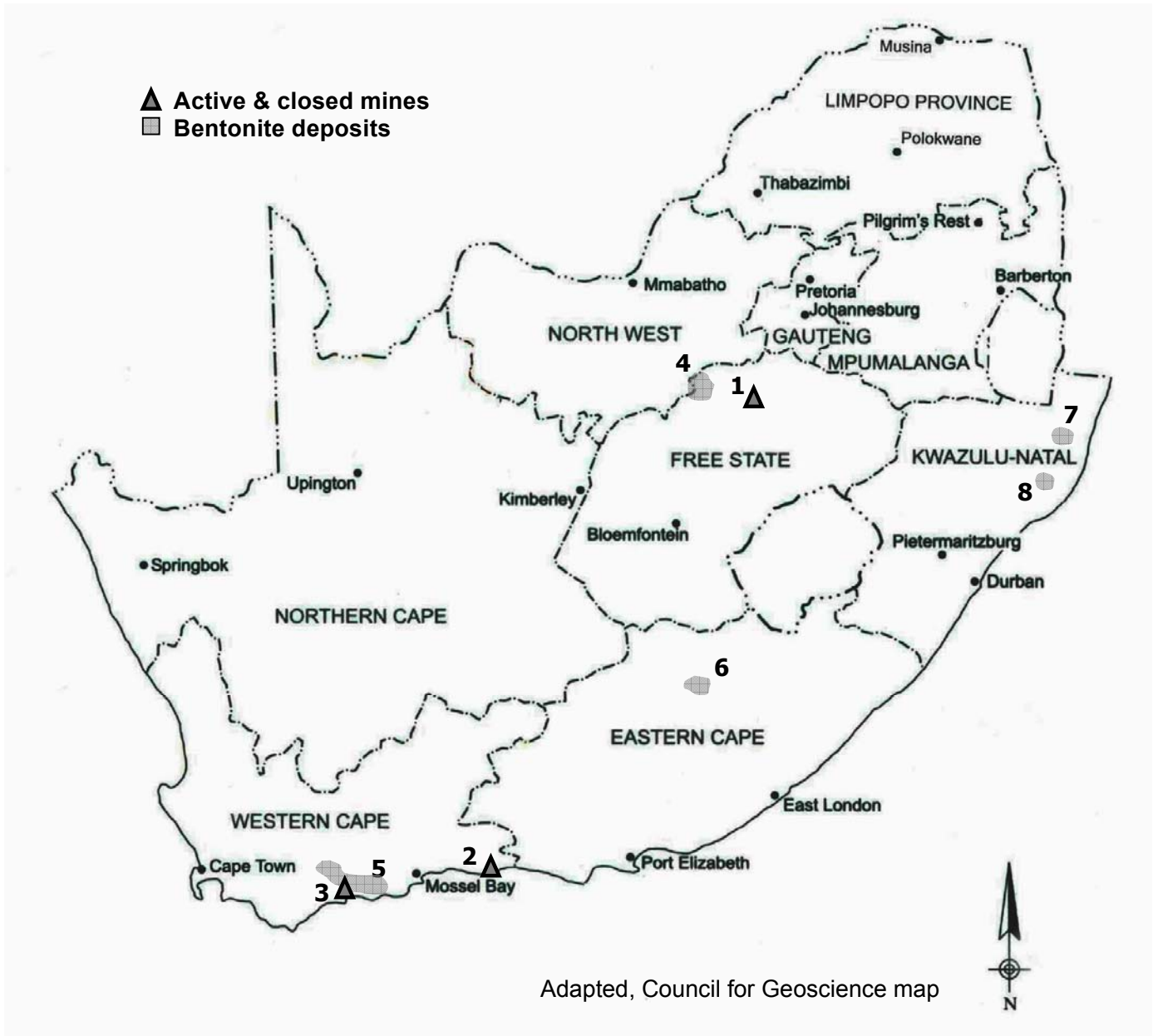
The Plettenberg Bay deposit is located some 5km west of Plettenberg Bay and is part of a succession of clay and sand layers with an overburden of varying from 0,1 to 61 metres. The lenticular shape of the bodies seem to suggest that deposition occurred in relatively small, shallow embayments which hosted low-energy regimes within a fluvial environment. The clay bodies dip in a southerly direction and are irregular in shape. This particular bentonite is a partial sodium bentonite (compared to that of the Koppies deposit) and the main exchangeable cations are Na^+ and Ca^{++} cations.

The deposit in the Heidelberg district in the southern Cape occurs near the Langeberge some 250km east of Cape Town, and originates from the deposition of volcanic ash associated with faults that controlled the opening of the Cretaceous basins. The material occurs in large beds dipping in a northerly direction towards the mountains. The bentonite layers are selectively mined and are generally overlain by soft siliceous sandstones and zeolitic tuffs. The bentonite in this area is a sodium/magnesium material, which forms a viscous gel in the natural state with the main exchangeable cations being Mg^{++} and Na^+ and auxiliary cations Ca^{++} .

An impure deposit of bentonite is found near Mkuze in the Ubombo district in Northern Kwazulu Natal. Little is known about the deposit but it appears to have been formed by the alteration of perlite, perlitic pillow lava and tuff.

The Groenfontein deposit in the Free State, is of marginal grade. The orebody profile suggests that optimal extraction can only be done if the co-product(s) are mined.

Diagram 3: Simplified map of South Africa's major bentonite mines and deposits



Deposit	Nearest district / town
1	Koppies, Ocean Mine, G & W Base & Industrial Minerals, active mine
2	Plettenberg Bay, Plettenberg Bay Mine, G & W Base & Ind. Min., closed mine
3	Heidelberg, Cape Bentonite Mine, Ecce Holdings, active mine
4	Groenfontein, Orkney, ex-mine, Ecce Holdings
5	Riversdale-Heidelberg deposit(s), includes Spiegelsrivier & De Doorn Rivier
6	Jamestown deposit
7	Mkuze deposit
8	Hluhluwe deposit

5. Reserves and Resources

Reserves of bentonite are in excess of 8 Mt although not all of it is considered to be economically mineable. Annual or biannual exploration and drilling programmes are typical of South African bentonite producers, although exploration is not pivotal to the success of the company *per se*. Cut-off grades are determined more so by overburden thickness than ore content. Most operations work on a 10-year “continuous mining plan” – thus the reserve base is continually being graded upward.

In the Heidelberg region (Western Cape), an overburden of more than 15-20 metres would make a high-grade deposit uneconomical – the undulating topography and lenticular nature of deposits have forced producers to mine up to 8 orebodies simultaneously. In the Koppies area (Free State), the orebody is well developed, extends over several kilometers and is near-surface, with an overburden of less than 2 metres.

There appears to be no shortage of quality bentonite reserves in South Africa. Reserves have been estimated to be sufficient for at least 67 years at the current production rates of 120 kt/a, and for 57 years at a production rate of 140 kt/a. Three medium/ high-grade deposits have since been discovered, although none have been accurately delineated – the one is an extension of the Koppies orebody, the other a marginal deposit and the third has major logistical problems.

6. Pit and Plant Processing

The orebody shape and general topography of the area determines what style of mining would be appropriate, e.g.: In the Heidelberg region (Western Cape), excavators and ADTs are used, as the material has to be hollowed out or scraped from a rock face. In the Koppies area (Free State), minimal overburden and the extensive nature of the orebody promotes extraction via front-end loaders, dozers and ADTs (Diagram 4A).

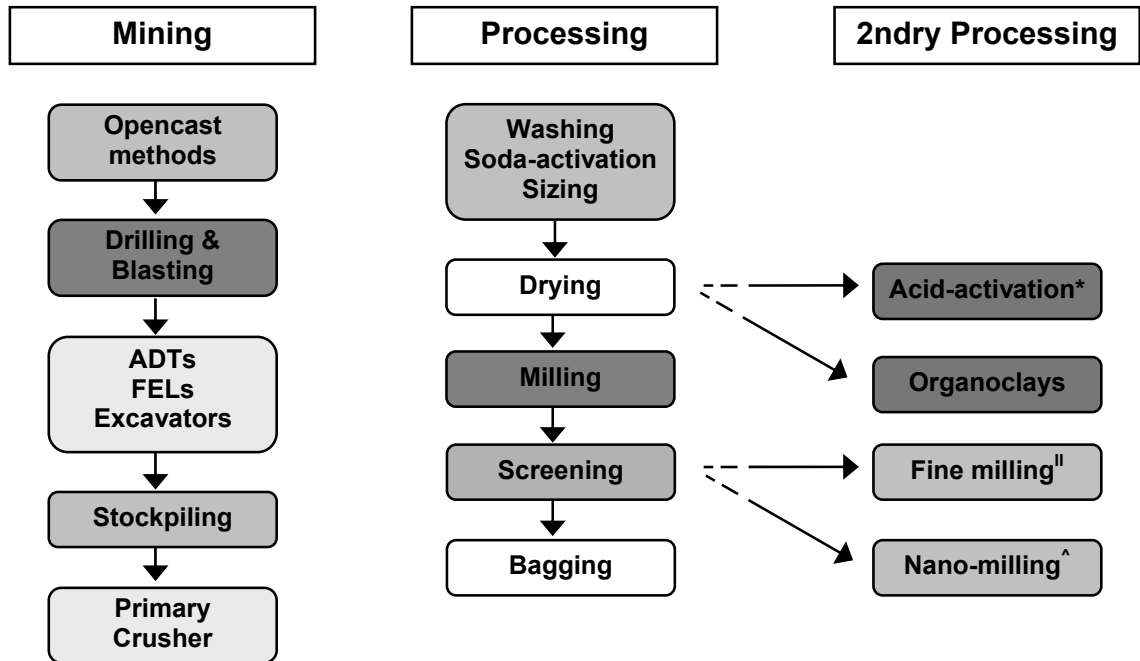
At least 60% of beneficiation is done on-site. This includes primary crushing, soda activation and washing (in no specific order) as well as drying and screening. Additional processing would include milling and granulation (100% passing 75µm sieve) – either done on-site or at a nearby plant; followed by either a) selling of individual calcium and sodium bentonite products, b) blending of both bentonites (marginal), c) acid-activation of calcium bentonites (<17% of local sales by volume) or d) fine milling or micronizing of the processed product. For the purposes of this report, secondary processing would include acid activation, fine milling and nano-milling. Local producers describe their plant technologies as ‘modern’ and ‘pioneering’.

It is important to note that all bentonites in South Africa have some form of soda ash addition/ activation, so as to optimise swelling properties. A large proportion of locally available calcium bentonites are acid-activated to induce enhanced surficial properties. The oil clarification industry is a major consumer of acid-activated bentonites. Afchem, a division of Süd-Chemie, is one of the major producers of acid-activated bentonites in South Africa.

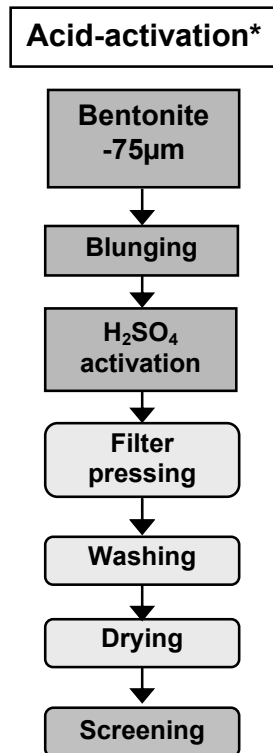
Acid-activation process steps include, blunging, H₂SO₄ activation and filter pressing (Diagram 4B). Bentonite is filtered off from the excess acid and the dissolved metallic salts, and washed very thoroughly. All the adhering acid residues and metallic salts are completely removed. Following the washing process, the filter cake is dried, and adjustable classifiers guarantee the desired particle size distribution required to obtain a bleaching earth with high activity and, at the same time, excellent filtration properties.

Diagram 4: Pit and plant processing flow diagram (A) and acid-activation (B)

A



B



Notes: * Acid-activated volumes < 15% of local sales
 II Micronised milling, particle size < 10µm
 ^ Nanoscale milling, particle size < 1µm

7. Product Overview and Applications

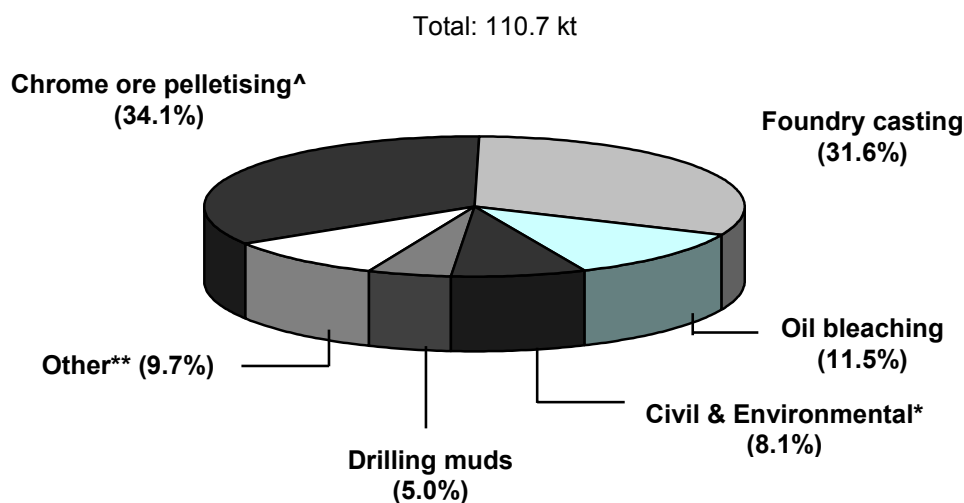
Bentonite's physical and chemical properties are of equal importance. Cation exchangeability, thixotropic and decolouring properties are among its important characteristics. Other specifications would include particle surface area, particle size, manganese, potassium and iron contents, colour, purity, charge per unit area and efficiency in acidic and/ or basic conditions.

In South Africa, bentonite is used in five principal applications (Graph1):

- ▶ Binder/ pelletising agent for ferrochrome (34% of total bentonite consumption),
- ▶ Foundry casting (32%),
- ▶ Oil bleaching industry (12%),
- ▶ Civil / environmental applications (8%), and
- ▶ Drilling muds (5%).

Smaller niche markets (< 10% of total) include: absorbents and clarifying agents (in beverages, edible and mineral oils), as a plasticiser, thickener, filler and suspending agent in ceramics, paper processing, agriculture, paint, chemical and pharmaceutical industries (see *Addendum 2*). Through continuous research and development, local bentonite producers have developed and launched tailored products to cater for specific client and -industry needs.

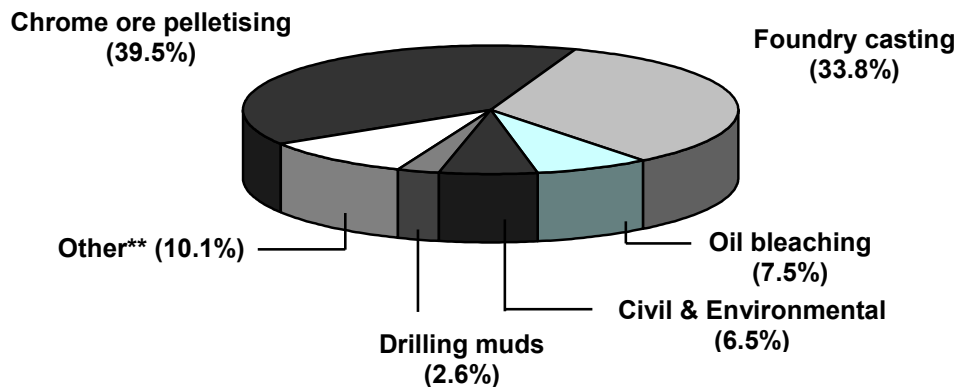
Graph 1: Primary markets, by volume, for all bentonite products in 2003¹



- Notes:
- ¹ Includes Mozambican and 'other' imports, totalling about 18kt & 6kt respectively
 - [^] No iron ore pelletising in South Africa.
 - ^{*} Includes dam sealants, grouting, piling, mining, landfill liners and GCL
 - ^{**} Includes cat litter, animal feed, pharmaceutical, wine clarifying, paint, paper, functional filler and extender applications.

Graph 2: Primary markets, by volume, for all bentonite products in 1990

Total: 41.0 kt



Source : Mineralogical Association of South Africa, 1991

In 1990, chrome ore pelletising and foundry casting markets comprised a larger segment of total bentonite consumption, with oil-bleaching still in its infancy (Graph 2). Drilling muds and civil applications have more than quadrupled in sale volumes over the last 14 years.

7.1 Bonding, Filling, Carrying and Thickening

Two types of bentonite are generally used: pure sodium bentonite with high swelling and gelling properties and a blend of sodium and calcium bentonite with lower swelling but still retaining high bonding properties. Bentonite's unique ability to bind, trap and 'layer' water and other cationic components is extremely important in bonding, filling, carrying and thickening processes.

7.1.1 Chrome ore pelletising

The **Outokumpu process** involves the wet milling, pelletisation and high temperature sintering of chromite fines, followed by the pre-heating of the total charge (including lumpy ore, coke and fluxes) in a separate shaft furnace situated above a closed electric arc furnace. The Outokumpu process reduces power consumption significantly relative to smelting of unagglomerated ore. Of the 6 local ferrochrome producers, 4 have built Outokumpu plants.

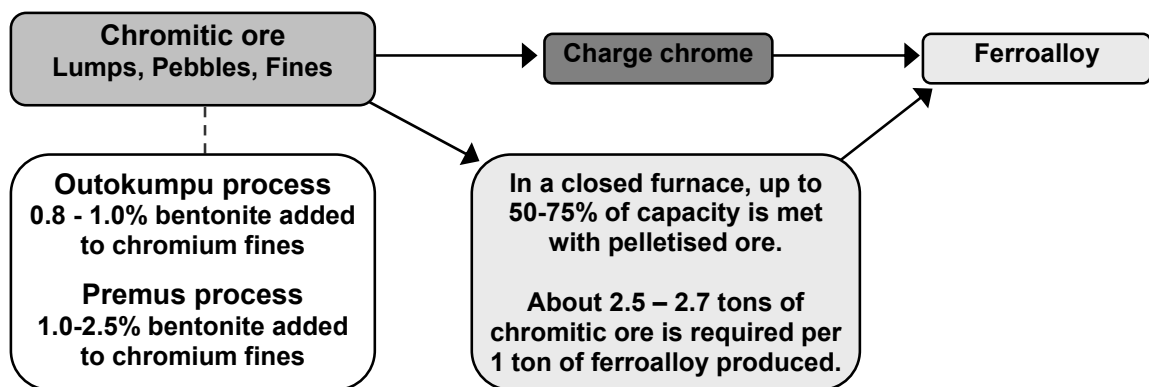
At least two ferrochrome producers are considering/ have switched over to the **Premus process** for several reasons: the process consumes up to 33% less power, has a lower coke consumption and the final product, charge chrome, contains significantly lower silica. The Premus process uses between 1,5 and 3 times more bentonite per ton chromium fines consumed (Diagram 5).

South African chromium mines produce larger quantities of fine ore (-1mm) than lumpy ore, hence the need for pelletising units. The blended ferrochrome fines or green pellets are bound together by the capillary force between water and the chromic concentrate particles. The addition of bentonite extends the time duration of water trapped in the pellet and improves the homogeneity of the ad-mixture. After drying, the adhesive forces hold the grains together. The electrical attraction and dipolar forces between the electrically charged concentrate particles and the bentonite particles give a considerable good compressive strength for dried pellets (see *Outokumpu Flow Sheet, Addendum 3*).

The high green and dry compressive strength of Na-bentonite, as well as its superior strength at higher temperatures have made it the binder of choice in chrome pelletising. Natural Ca-bentonites provide a high green strength, but low dry compressive strength as Ca-bentonite loses its waters of crystallization at lower temperatures, as opposed to Na-bentonite. Though less efficient, soda-activated Ca-bentonite offers an ideal, cheaper alternative to Na-bentonite in chrome pelletising.

The typical specific surface area of natural calcium bentonite is 600,000 - 1,200,000 cm²/g. Particle size distributions should ideally be: 100 % -74µm, 95 % -37µm and 65 % -10µm. The water absorbency of bentonite in chrome pelletising should be more than 600%, although values above 500% are acceptable in some cases.

Diagram 5: Bentonite consumption in ferroalloy manufacture



7.1.2 Foundry casting applications

Bentonite's excellent absorbent and plastic characteristics, allow for easy binding of foundry sand grains, whilst after drying, the superior permeability of the composite allows for reaction gases to penetrate through the mould walls without damaging the structure (thereby limiting defects and rejects in the casting process); bentonite binders also reduce cast "knockout" time.

Additional advantages of bentonite over other binders include its: high dry strength to prevent mould erosion, high green strength (which is necessary with modern, high pressure "boxless" moulding), high hot strength to maintain mould shape during metal solidification, high durability to withstand higher casting temperatures, and rapid bond development for high production foundries.

In green sand moulding, the sand mix consists of silica sand, bentonite (about 2,5-3% per ton sand) and/or another activating clay or carbon dust (which may vary between 0-6%). More bentonite is used in the "facing mould" (up to 5% of sand volume) than in the "backing mould" (less than 2,5%). Bentonite consumption per cast item has remained unchanged over the last 10-15 years.

7.1.3 Iron ore pelletising

The inherent hardness of South African iron ore prevents it from being pelletised. Very few fines are generated in local iron ore beneficiation. Further, it has been found that pelletising is too expensive and unnecessary in the South African context, as steel producers have designed their blast furnaces specifically for local iron ore products, which typically require 0,2-5mm (fines), 5-10mm (coarse sinter) and 13-25mm (lumpy).

Local steel producers typically use an iron ore mix composed of 30-40% lumpy ore, with the remainder being fines and sinters. Consumers abroad prefer mixing lumpy and sinter-grade South African ores with softer Brazilian and Australian fines. Brazilian and Australian iron ore is of such a nature that its inherent softness and the large volume of fines produced in beneficiation, necessitates pelletising.

7.1.4 Pharmaceuticals and cosmetics

In cosmetics, bentonite acts as a thickening agent, keeping preparations such as shampoos, calamine lotions, facial creams and lipsticks in a homogenous, non-greasy form, whilst maintaining correct moisture levels. As an inorganic, inert mineral, bentonite is preferred over most other thickeners. Bentonite also has small but effective antacid properties and is often used as a mould-release agent in the manufacturing of latex products.

Bentonite is used as an excipient and binder in tablet manufacturing. Further, it acts as an excellent base-medium for ointments, pastes and creams. Bentonite's water retention capabilities are also used in anti-diarrhoeal medicinal suspensions or syrups; other pharmaceutical applications include the identification and preferential isolation of vitamins, enzymes and catalysts; and in pharmaceuticals soaps as an adsorbent and degreasing agent.

7.2 Refining of Edible and Mineral Oils

Bentonite used in this application is acid-activated to enhance the surficial and chemical properties already present in the clay. Afchem is the largest producer of acid-activated bentonite (AAB) in South Africa. The local oil-bleaching market requires about 3 kt p.a. of AAB products – thus more than 60% of ABB products are exported.

In **edible oil refining**, bentonite removes a variety of impurities such as phosphatides, fatty acids, gums and trace metals from vegetable and marine oils; it also decolourises and deodorises oils. In **mineral oil refining**, most industrial lubricants can be reclaimed and restored to acceptable specifications after treatment with acid-activated bentonite. The clay removes water, residual additives, degradation products and other contaminants.

7.3 Drilling Mud

Bentonite is one of the main constituents of drilling mud used in the exploration for oil and gas. The oil industry's specifications for bentonite material are stringent and thorough. The high natural viscosity, good gelling characteristics and superior water retention capabilities of Na-bentonite are favoured for this application.

Bentonite serves as a sealant for porous rock; acts as a lubricant for the drilling bit and reduces friction on the rotation of drill pipes; and has good thixotropic properties – it carries cuttings to the surface while the bit is turning, and when drilling stops, forms a gel which prevents cuttings from returning to the bottom of the hole and jamming the bit.

7.4 Civil Engineering and Environmental Uses

Civil engineering applications provide a niche market for bentonite, where it is traditionally used as a thixotropic, support and lubricating agent in diaphragm walls and foundations, in the construction of tunnels, in horizontal directional drilling and pipe-jacking. High-swelling sodium bentonite is used as a sealant in the construction and rehabilitation of fresh water dams, lagoon reservoirs, highly-contaminated waste-water lagoons, landfill areas and other structural or building activities which require water seepage containment.

Bentonite is used as a low permeability barrier in the basal and cap lining of landfills as well as in the construction of peripheral, vertical cut-off walls. Bentonite products are also necessary for the production of geosynthetic clay liners (GCLs). When bentonite comes into contact with water, it expands 20 to 30 times its dry volume, thereby effectively sealing off any ground structure from water seepage.

The swollen bentonite is highly flexible and therefore small ground movements will not damage the layer. Civil engineering markets have grown significantly over the last few years, particularly because of bentonite's long-term containment capability, chemical resistance, environmental compatibility and ease of installation. Growth markets include bentonite sealants for gold and coal operations where acid mine drainage is a problem.

7.5 Wine and Fruit Juice Refining

Both sodium and calcium bentonites are used to remove impurities such as fine proteins from wine and fruit juice. However, sodium bentonite is preferred as it is more effective in reducing proteins and does not remove as much aroma and taste from wine. Bentonite for this application must be free from impurities as the final products will be used for human consumption.

"Fining" is the name given to the clarification phase of wine making and can be initiated before or during fermentation. Filtration is done using industrial filtration machines and chemical additives such as bentonite. Bentonite is used in industrial filtration machines, where it acts as an electrochemical clumping agent for solids, suspended fine proteins and grape tannins. The solids settle at the bottom of the solution and are then removed.

7.6 Nanoclays

A potential new value-added growth market for montmorillonites is nanoclays. Nanoclays are clays consisting of nanometre-thick platelets that can be chemically modified to make clay complexes compatible with organic monomers and polymers. Montmorillonite's spathic crystalline structure means that the mineral will disperse completely within the polymeric structure.

Montmorillonite-based nanoclays are high-specific surface products, with lamella that have a high surface to thickness ratio. The limiting properties of polymers, which include their stiffness and/or strength in durable applications, gas permeability in packaging materials and distortion under high temperatures, can be significantly improved through the use of nanoclays.

Organoclays, acid-activated clays and nanoclays are produced using a wet process (see *Pit and plant processing*, pg.9-10). Nanoclay production requires an intense grinding or shearing to delaminate the montmorillonite into very thin flakes before organic compound addition. Much research is still being done to 1) unlock the properties of nanoclays, 2) improve compound combinations and efficiencies, and 3) reduce unit costs of the manufactured product.

7.7 New Applications

Dye-removal: Wastewaters from dyeing and finishing operations in the textile industry are generally high in both colour and organic content (about 12% of synthetic textile dyes used each year are lost during textile processing and 20% of these lost dyes enter the effluent stream). Calcined bentonite/TiO₂ composites (material containing TiO₂ particles evenly distributed through a calcined bentonite's lattice layers) are highly active in degrading organic compounds, e.g. the decolouring ratio for bright red solutions is 93.6%, which is much higher than pure TiO₂ and similar materials. Effective substitutes include activated carbon and fly-ash.

Lightweight aggregates: Lightweight aggregates (pelletised products from the sintering of fly ashes with bentonite or pulverized coal) are extremely important where strength, consistency and reduced weight (up to 25% lighter than normal concrete) are needed. Further, these bentonite products reduce dead-load, improve fire resistance and shock absorbency (particularly when needed in arrestor beds), exhibit excellent thermal properties and show superior elasticity. Lightweight aggregates are used in tunnel linings, precast and concrete products, roof/ floor screed, arrestor beds, filter media, roof tiles, land drainage and geo-fill applications.

Nano-plastics & fibreglass: Invisible desiccants (desiccants integrated directly into packaging material through injection-moulding), offer maximum humidity protection, improve overall design and efficiency of final products and reduce the need for conventional desiccants (thus saving on transport costs). Nano-sized bentonite provides the 'seed chambers' for desiccants imbedded into the plastic. In cable manufacturing, functional plastics contain nano-sized bentonites that reduce splitting, retard melting and prevent dripping of melting cables. The replacing of fibreglass and carbon fibre with bentonite nano-particles is receiving noticeable interest at present – benefits would include improved rigidity and reduced weight per unit area.

Polypropylene-composites: Several tests with bentonite-filled polypropylene have shown that tensile strength, elongation at break, impact strength and degradation temperatures decrease with increasing bentonite filler loading. Morphological and thermogravimetric investigations revealed that these reductions were due to an agglomeration of bentonite particles, particularly for composites with high bentonite loading. However, the percentage water absorption showed an increase with increasing filler loading.

Water retention and treatment: Bentonite sealants/ liners have shown strong growth in the last 3 years, particularly with decorative water features, i.e. any man-made stream, fountain, waterfall, or pond that contains water for landscape purposes. These consumer-oriented markets require convenience, performance and safety. Certain bentonite products have been specifically designed for water clarification and the removal of phosphorus, organic and inorganic contaminants. These products feature time-released, water clarification activators for water treatment.

Pulp and paper manufacturing: As paperboard mills continue to strive for increased water closure to meet environmental concerns, the use of retention/ drainage/ formation aids to improve colloidal retention, particularly in micro-particle retention, is expected to increase. In alkaline fine paper production, micro-particle systems that utilize bentonite are set to increase their market share significantly, as 1) more paper mills improve their water reticulation circuits, 2) fibre recycling increases, and 3) the benefits of on-site polysilicate microgel technologies are realised.

Clarifying agents: Innovative products for wine clarification include composites, (e.g. copper citrate sprayed onto an inert bentonite base) which specifically target hydrogen sulphide odours and the elimination thereof in wine and fruit juices. Benefits of this product include: safer, lower residual copper contents than current copper sulphate treatments, a higher specificity to sulphide than copper sulphate, no additional blue fining needed, no uptake of silver ions and an overall reduction in toxicity.

Bentonite fibre technology: When bentonite fibres are formed under certain mixing conditions it becomes a more effective binder. Using roll-mixing technologies, bentonite fibres doubled iron ore pellet strengths and allowed the dosage to be cut in half; whilst in green sand moulding, fibres can improve dry compressive strengths from 50 to 370 psi.

Table 2: Typical chemical analysis of bentonite samples

CHEMICAL COMPOSITION ^T	G & W BASE & IND. MINERALS [KOPPIES DEPOSIT]			ECCA HOLDINGS [HEIDELBERG DEPOSIT]				OTHER							
	Ocean MD – General uses*	Ocean H.V. – Drilling uses*	Ocean MD – Foundry uses*	Soil sealants*	Foundry uses*	Drilling mud*	Wine & fruit juice decolourant*	Trimex Bentonite, India**	Surrey bentonite (Ca-bento.), UK	Acid-activated Mylos, Greece	BKU, Wyoming Bent., USA [#]	Wyoming bentonite, USA	Ayun Musa, Egypt	Volclay, GP Na-Bentonite	Ozurgeti District, Georgia (Russia)
SiO ₂	59.1	59.1	59.1	66.8	65.9	64.9	66.0	52.0	55.2	54.2	66.0	55.6	52.5	61.0	55.1
Al ₂ O ₃	18.6	18.6	18.6	17.0	18.0	17.6	17	17.0	13.7	16.4	17.6	18.1	17.6	19.0	18.5
Fe ₂ O ₃	4.4	4.4	4.4	3.1	2.8	5.4	2.5	6.0	8.1	5.6	4.0	3.6	8.4	4.0	1.8
TiO ₂	na	0.2	0.2	0.2	0.3	0.4	0.1	na	0.7	na	0.2	0.1	1.2	na	0.4
CaO	1.9	1.9	1.9	0.5	0.3	0.4	1.0	1.2	6.3	4.6	1.0	1.0	2.8	2.0	1.5
MgO	4.0	4.0	4.0	3.4	4.0	2.1	3.0	na	3.3	3.4	1.8	1.9	1.5	2.0	3.3
K ₂ O	0.3	0.3	0.3	0.5	0.4	1.1	0.4	0.2	0.6	0.5	0.5	0.4	1.3	na	2.7
Na ₂ O	2.5	2.5	2.5	3.0	2.6	1.6	2.5	1.5	<0.1	2.7	2.2	1.6	2.0	3.0	2.3
LOI	8.9	na	8.9	6.6	5.4	6.6	7.5	10.0	9.9	10.3	na	8.0	12.1	6.0	11.3

Notes: ^T Expression of elements as oxides results from standard chemical analysis method.
Elements are not present in bentonite as oxides.

* Na-activated products

** Ceramic grade bentonite, regional locality unknown.

[#] BKU – Black Hills Unaltered Bentonite

^{||} GP – Processed, granular Na-bentonite, used in hydrobar tubing

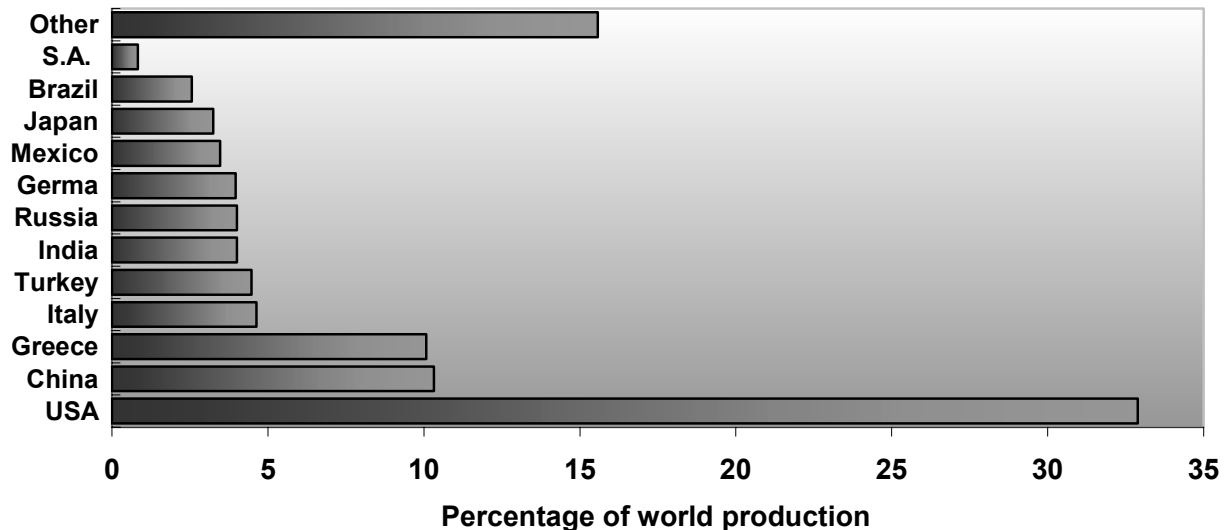
8. Supply and Demand

8.1 Supply

South Africa is ranked 19th in the world in terms of bentonite production and contributes 0,6% in volume to global production (BGS, 2002). The USA, China and Greece account for about 53% of world production, whilst Western Europe accounts for 27 percent (Graph 3). The major world and US bentonite producer is American Colloid Co. (Amcol), producing 1,45 Mt p/a of bentonite from all of its US operations; the second largest producer is Silver and Baryte of Greece, producing 1 Mt p/a. The principal world markets for bentonite are in foundry, oil drilling and cat litter uses. Major exporting countries, in descending order of volume, are Greece, USA, Italy, the Netherlands and China, accounting for about 65% of world bentonite exports (Graph 4 & Addendum 4).

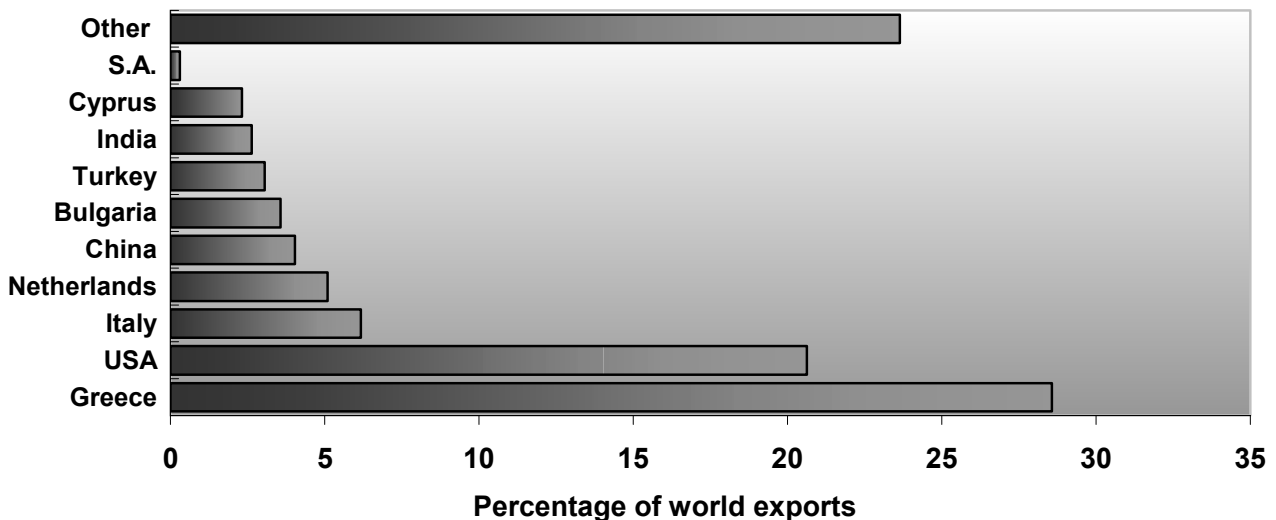
Graph 3: World bentonite production, 2002

Total: 12.5 Mt



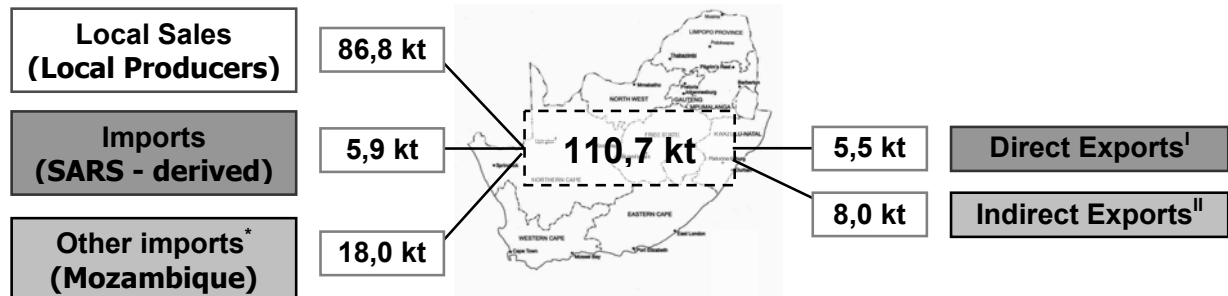
Graph 4: World bentonite exports, 2002

Total: 3.5 Mt



In 2003, bentonite supplied to the South African market totalled about 110,7 kt of which 78,4 percent (86,8 kt) was from local sources and the balance (23,9 kt) from imports. About 18kt of bentonite was imported from Mozambique and a further 5,9kt from sources abroad (Diagram 6).

Diagram 6: Bentonite mass balance, 2003

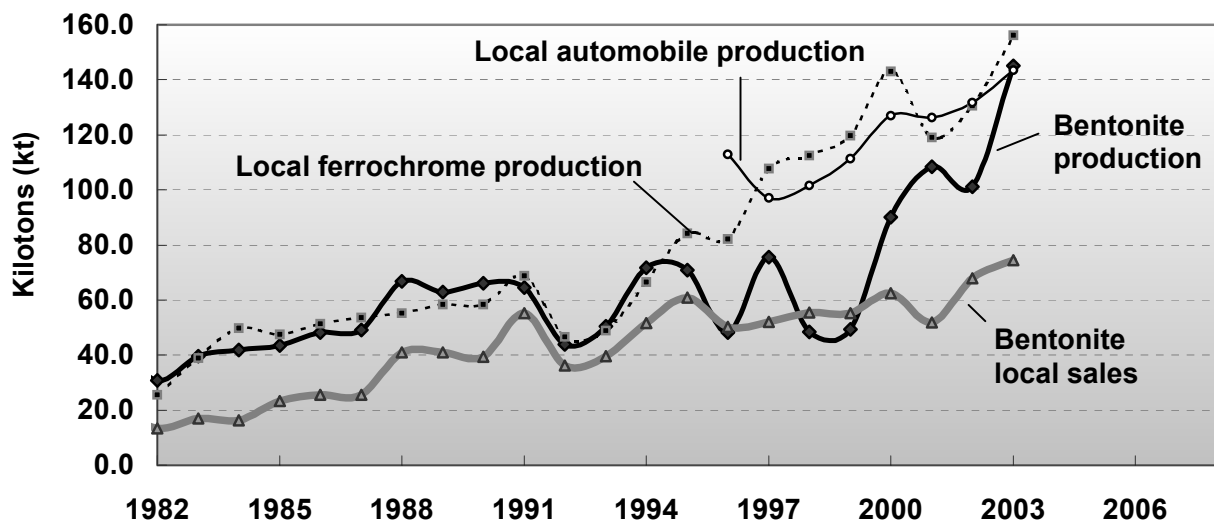


Notes: * Not included or recorded by SARS
^I Exports by local producers
^{II} Exports by processors & manufacturers, e.g. AAB producers

Production centres are limited to the Koppies (OFS) and Heidelberg (Western Cape) regions at present. The remote location of bentonite mines has forced secondary processing plants as well as depots/ warehouses to be positioned much closer to major consumers, particularly chrome producers and foundries. Through campaign mining (high-volume mining over a 2-3 month period), annual production levels can be as low as 25-30% of installed capacity, although the industry average is about 60%. Plants generally run at about 80-90% of installed capacity.

In 2003, production and local sales volume increased by 43,6% and 5,1% respectively (FOR) (Graph 5 and *Addendum 5*). Bentonite production and local sales (by volume) have grown by 31% and 7,8% y-o-y over the last 4 years; however, campaign mining has skewed annual production figures (e.g. 1997 and 2000-2002) over the last 15 years. Local sales, by value, and prices have decreased although this is misleading as producers sell their products to sister companies through internal transfers. Superimposed on Graph 5 is local ferrochrome and automobile production.

Graph 5: South Africa's production and local sales of bentonite, 1982-2003



Plants will be able to accommodate any new bentonite demand in the foreseeable future, particularly from growth industries such as foundry castings (used mostly in automobile component manufacture), pelletising and civil applications. No major capacity overhauls have been planned at any bentonite plants for the next 2 years.

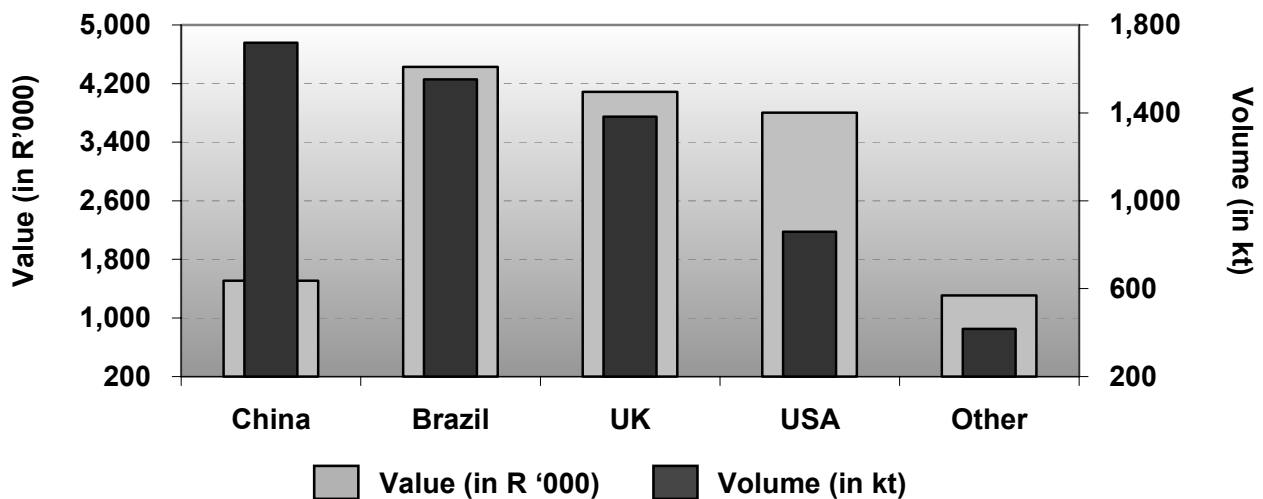
8.1.1 Exports & Imports

South Africa's exports are negligible compared to world totals. In 2003, bentonite exports amounted to some 11 kilotons with a value of R4,5 million. Target markets include the oil and civil industries. Discrepancies do exist between the DME figures and that of SARS – this is primarily because companies reporting to DME do not export products directly, but through agents. Exports are shipped to South America, the Middle East, Far East and Europe. About 60% of locally manufactured, acid-activated clays are exported – major markets include sunflower- and mineral oil refining. The majority of producers believe that exports are only viable at R7,50/US\$.

In 2003, major imports, in descending order of magnitude, were from China, Brazil, UK and the USA. Low-value products were imported from China (<R880/ ton), whilst the highest-value bulk tonnages (>1kt) were from Wyoming (USA), priced at R3 800/ ton (Graph 6). Super-grade bentonites from the Netherlands and France fetched prices of R38 000/ ton or more (Graph 7).

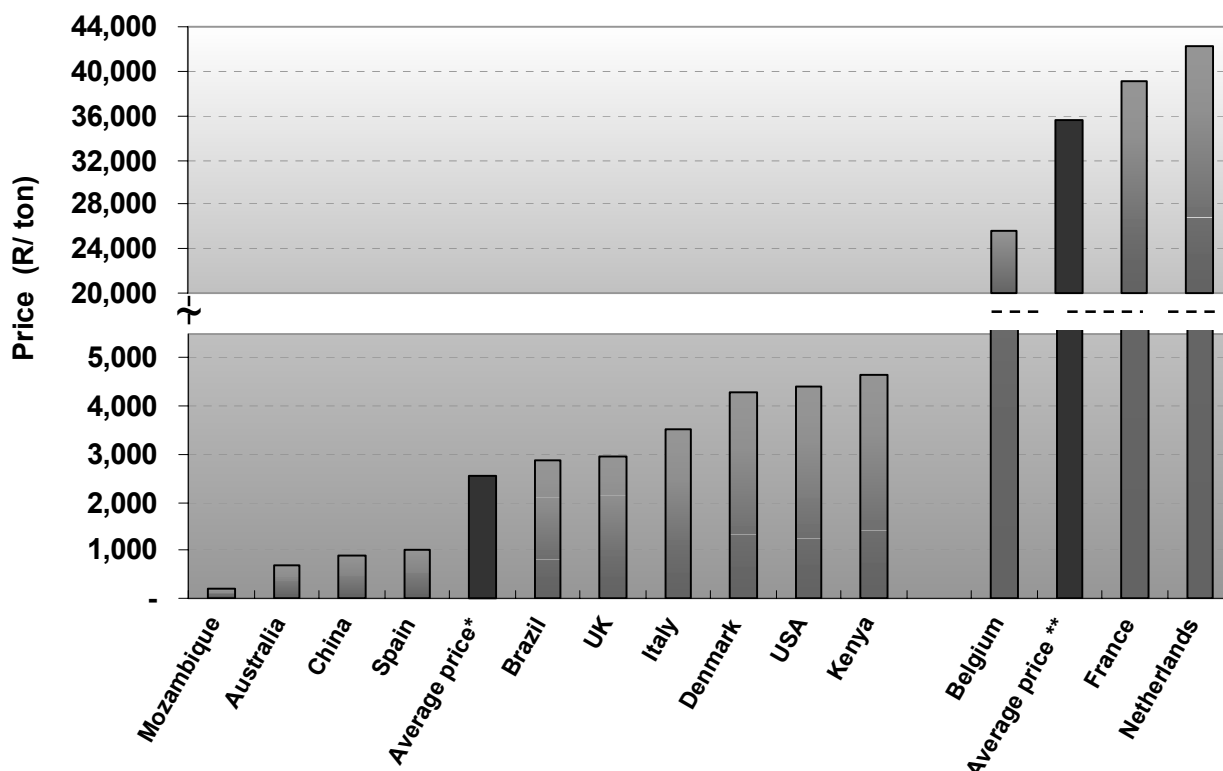
Mozambican imported volumes have been exceptionally variable over the last 10 years, partly as a result of no active mining there – all material is scavenged from mine dumps amassed in the 1970's and 1980's. New deposits have been located, delineated and sampled, whilst mining should commence within the next 2 years. Industry sources have noted that not all imported material has been accounted for by SARS Customs – local producers suggest that an additional 3-4kt of imported bentonite (excluding Mozambican imports) is traded in South Africa.

Graph 6: Bentonite imports, by value and volume, 2003



Source: SARS 2004

Graph 7: Average price of imported bentonite, 2003



Notes: * Price for high-quality bentonite products < R5 000/ ton
 ** Price for superior-grade bentonite > R5 000/ ton

Source: SARS 2004

8.2 Demand

More than 85% of South Africa's demand for bentonite is fully met by local production. Exports are currently conducted only on a small scale (about 13kt of value-added bentonite is exported). Bentonite consumption has increased by a year-on-year rate of 7,4% over the last 14 years. Markets that have shown the largest growth include oil-bleaching applications (all bleaching earths prior to 1988 were imported), drilling muds and civil applications (Graph 8). Growth in foundry casting and chrome ore pelletising markets has been directly proportional to capacity/ production increases in these respective industries.

Nano-technologies, though still in the R & D phase, are expected to grow significantly in the near future. Growth in the construction, mining and manufacturing industries has had a knock-on effect on civil and environmental applications for bentonite. This trend will continue with current low interest rates, buoyant property prices and the rapid development of certain industrial and urban areas in Gauteng.

With the addition of seven new pelletising plants in the next 3 years, capacities in the ferrochrome industry are expected to increase by 11-15% y-o-y until 2008. The strong world demand for stainless steel (which requires ferrochromium) will keep local producers under renewed pressure. The switchover to the Premus process (instead of Outokumpu) may require twice as much

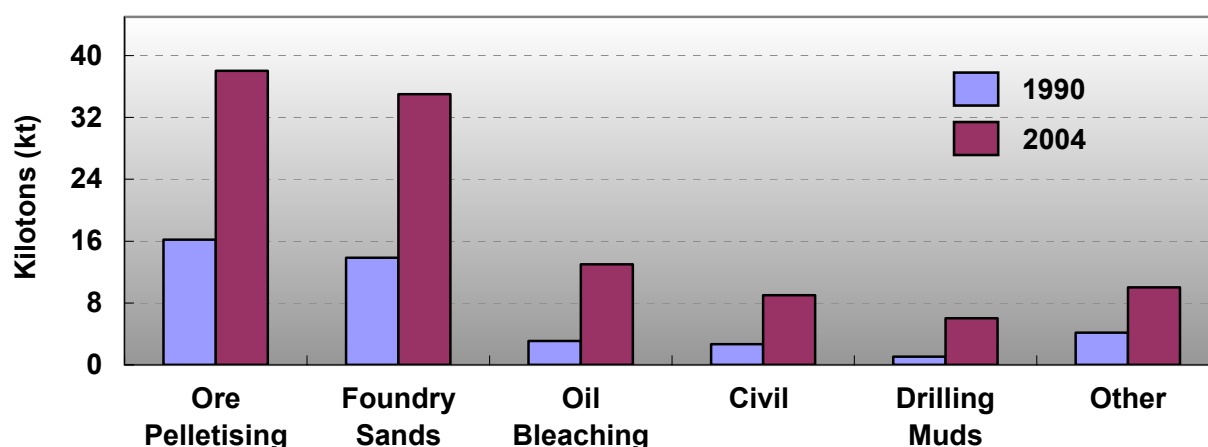
bentonite per ton chrome ore pelletised. Problems that will have to be factored into the chrome “roll out plan” include the escalating costs of coking coal, security of long-term power supply and the unrelenting low Rand/US dollar exchange rate.

Thus, principal drivers for growth would be ferrochrome, foundry castings and civil applications. Bentonite demand is set to grow at levels significantly higher than that of the macro-economy, at about 7% year-on-year.

Any growth in exports is singularly dependent on the foreign exchange rate – most producers favour a foreign exchange rate of R7.50-8.00/ US\$ (the Rand currently trades at less than R6 / US\$, January 2005). Should the Rand weaken to more ‘acceptable levels’, then exports are set to increase significantly (projected growth 12% y-o-y), but the expected influx of cheap, imported material remains a problem for local producers. Export growth markets include the oil-drilling and civil applications.

A new mill has been installed at Ecca’s bentonite mine near Heidelberg, Western Cape – the aim is to produce a finer fraction of bentonite powder. Other producers are also conducting feasibility studies on fine milling technologies.

Graph 8: Local bentonite consumption trends, 1990 and 2004



8.4 Prices

The variation in price of bentonite can be ascribed to the fact that different grades are used for different applications, e.g. acid-activated bentonites (used in oil bleaching) fetch a far higher price than crude Ca-bentonite (used in ore pelletising). Mines often sell the product ex-mine with private contractors or the consumers’ own haulage lines handling transportation. No long-term agreements are in place, although ‘gentleman’s agreements’ exist whereby contract prices are negotiated or inflation-adjusted annually.

Contract prices most often include dispatch and delivery costs, thus prices reflected in this report are easily half that of real trading prices. Prices may fetch upwards of R600 per ton, up to R2 000 and higher, depending on distances travelled, volumes required, insurance costs, etc. Prices have marginally increased year-on-year, with inflation, energy and transport costs being the main price determinants.

8.5 Substitutes

Bentonite is a unique material and only a few substances have similar properties. Acceptable substitutes must adhere to the following prerequisites: low cost, high performance and general availability of product. Bentonite substitutes have been developed in several niche markets, these include:

8.5.1 Dam Sealing

A plastic lining, although more expensive, can be used. Ponds and reservoirs are sometimes sealed off with a concrete lining, whilst dams may use a relatively cheaper alternative such as bitumen lining.

8.5.2 Pelletising

The use of bentonite as an ore binder can be a disadvantage: bentonite acts as a chemical contaminant in ferrochrome and iron ore. For each 1% bentonite added, the iron ore content is reduced by 0,6% and the silica content increases by about 0,5%, thus more coking coal and limestone are needed in the reduction process. Alternative materials that can be used are slaked lime, hydrated lime, organic-based materials, natural slimes and cement clinker. These substitutes have, in some cases, proved to be more expensive and are only used on a limited basis worldwide. None of them have achieved consumption levels similar to bentonite. In animal feed pelletising, molasses, organic binders, kaolin and attapulgite have replaced bentonite.

8.5.3 Paint

In thixotropic or non-drip paints, bentonite has been replaced to a great extent by organic thickeners and other alumino-silicates, e.g. kaolin.

8.5.4 Foundry Casting

Alternative foundry casting processes have been developed; these include resin- or polymer-bonded, chemically-bonded and petroleum-bonded processes, which do not require bentonite. It is unlikely that bentonite will be replaced in green sand applications, because it is an economic bonding medium that can be reclaimed after use. Substitute materials in the green sand moulding process include kaolin, fly-ash and coal dust.

8.5.5 Drilling Mud

In the oil drilling industry, oil-based compounds are the principal substitute for bentonite locally; whilst internationally, attapulgite is the primary substitute. In the presence of an electrolyte such as salt, bentonite flocculates and cannot maintain the high viscosities needed. Attapulgite, as a drilling fluid, is stable in salt-water environments and can be used in both marine and saturated brine or salt-rich environments.

8.5.6 Pesticides

The major competitors to bentonite in this application are diatomite, attapulgite and coal waste. Diatomite is the favoured substitute, although it is more expensive. Attapulgite is also used as a suspension agent in pesticides, especially when other clays may promote instability in the pesticide solution. Kaolin is also used as a suspension agent.

8.5.7 Wine and oil clarifiers

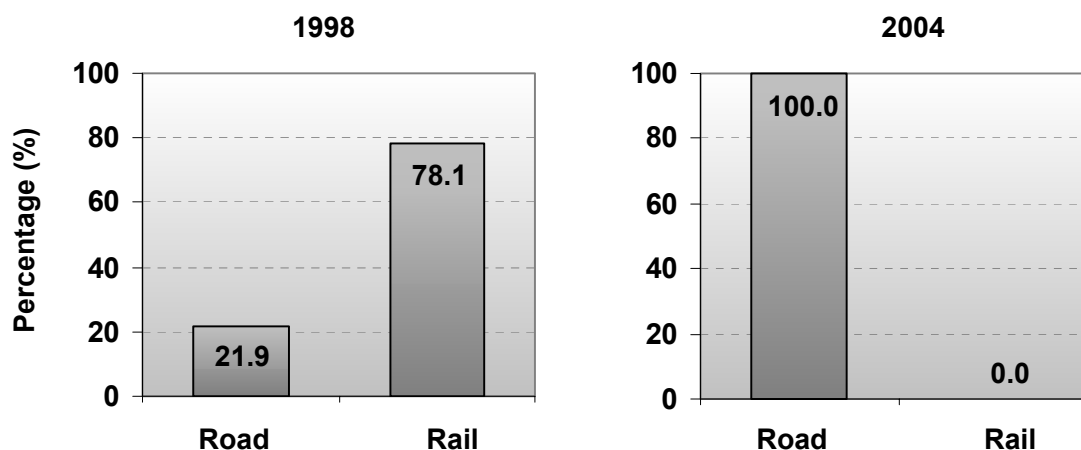
Synthetic resins could be the next wine-clarifying agent commonly used in 'fining'. New environmental safety regulations, particularly in the USA, are making it more costly to deal with the relatively large amounts of solid waste material produced through the bentonite fining method. In the past, the solid waste would go back into the vineyard, as fertilizer, however new legislation requires that substances containing alcohol are considered 'hazardous waste' and need to be removed through special means. Adsorbent resins are already used by the food industry to stabilize and decolourize sugar juices. Alumino-silicates that have substituted bentonite in wine clarifying include blended attapulgite.

9. Logistics and Transport

Turnaround times have improved, although this is not necessary with established customers where 3-month stockpiles are kept on-site at the consumer's premises. The rapid change from rail to road transport (Graph 9) as well as the vast customer base for bentonite products has led to the creation of marketing and logistics divisions by various companies to deal specifically with the placement of orders, order tracking, client problems and logistical/ transport arrangements – most companies have contracted out transport, albeit it at a lower profit mark-up and risk.

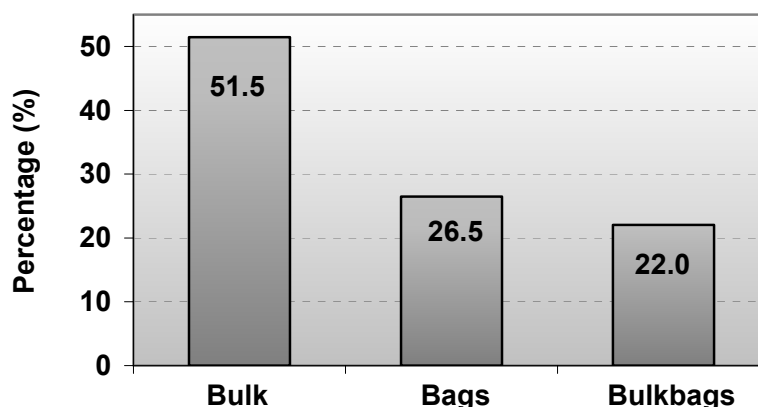
Road transport is the only mode of transport (100%), as opposed to 6 years ago where 21,9% of volumes sold were transported by road. Bulk transport is the dominant mode of transport by far (51.5%); bags (26,5%) and bulkbags (1 ton and 0,5 ton bags) representing about 22% of volumes sold (Graph 10). Bagged volumes are generally associated with high-value, low volume, product-specific niche markets. Transport costs have become an important factor in price determination – up to 55% of the consumer price may be transport-related.

Graph 9: Road / rail transport split for 1998 and 2004



Lack of reliability and slow delivery by Spoornet has seen road transport increase dramatically over the past 6 years. Road transport guarantees a quick turnaround time – within 24 to 48 hours a product can be despatched and delivered, anywhere in the country. Conversely, rail transport is expensive and unreliable for "access rail" clients, i.e. low volume, infrequent users of rail.

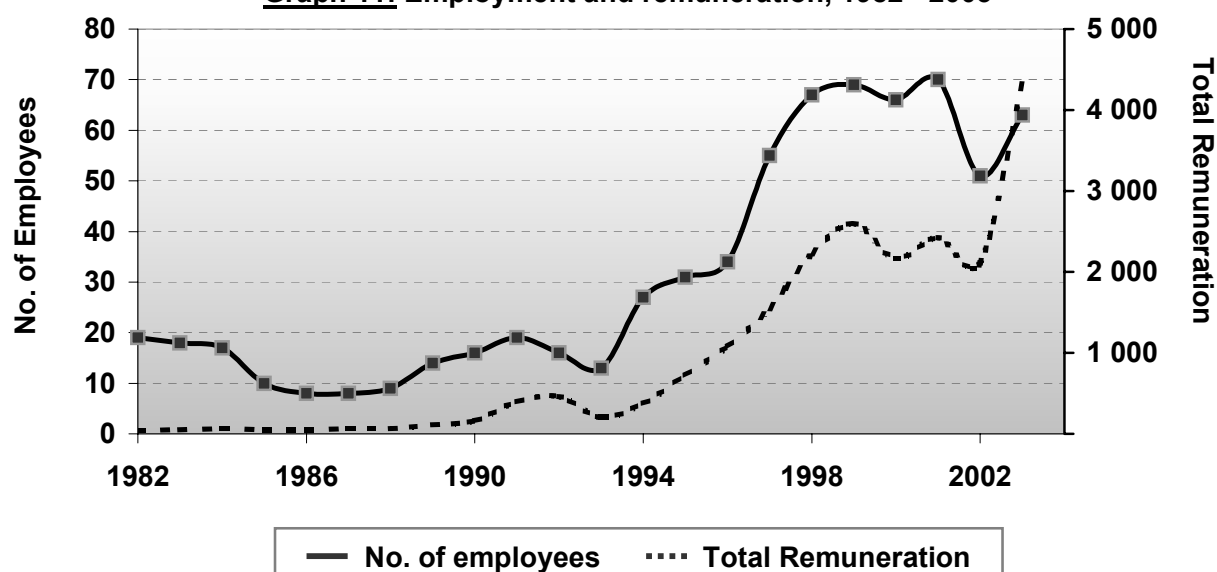
Graph 10: Packaging medium for bentonite products



10. Employment and Remuneration

There has been a steady increase in employee numbers since 1996 (Graph 11). This has been attributed to major pit and plant expansions. During campaign mining, contract workers are required for only 3 months of the year. Employee remuneration in the bentonite mining industry is average in the industrial sector – revenue generation is 0,9% of industrial mineral totals, whilst employee numbers and remuneration are about 0,6% and 0,7% respectively.

Graph 11: Employment and remuneration, 1982 - 2003



11. Environmental, Safety & Community Initiatives

All employees must wear hard hats and masks in mining and processing areas. Most companies have regular/monthly health checks, annual thorough physicals and annual chest X-rays. The use of dust hoods, dust collectors and other forms of dust suppression has minimized bentonite dust pollution significantly in production plants.

ISO 14001 and ISO 9001 compliancy, as well as NOSA accreditation, have assisted major role players in overall health and safety and proper environmental management. Employee compliance, with regard to mine health and safety is excellent, although external contractors seem less compliant.

All mining companies have been involved in community developments and social upliftment projects to some degree. This includes offering bursaries to prospective learners, upgrading and building schools and workers' accommodation and supporting HIV projects.

12. Threats, Problems and Risk in the Industry

Barriers for new entrants in bentonite exploitation and production would include:

- ▶ High start-up costs,
- ▶ Finding receptive markets,
- ▶ Acute product- and industry knowledge,
- ▶ Technical know-how regarding processing,
- ▶ Continued capital expenditure from day one,
- ▶ Correct orebody characterization and interpretation, and
- ▶ Finding a high-quality extensive deposit with consistent grades.

Currently, there is a definite skills shortage in South Africa regarding fine milling and processing of bentonite. The overall Industry risk is low to moderate. Factors that have ensured stability in the industry include:

- ▶ Extensive LOM plans,
- ▶ Significant 'barriers' for new entrants,
- ▶ A lack of competitively priced substitutes,
- ▶ New niche markets being developed regularly,
- ▶ Substantial, localised, high-quality ore reserves,
- ▶ Relatively stable supply and demand market forces,
- ▶ A good balance between major and minor consumers,
- ▶ A good relationship between suppliers and major clients, and
- ▶ Strong growth in the ferrochrome and foundry casting industries.

In a well-balanced market a new entrant needs a technological advantage (either in improving product properties or lowering unit processing costs) in order to be able to take the market share from established producers. In such a situation it is generally easier to purchase an existing operation, or an interest in one, than to start afresh.

13. Conclusions / Summary

Bentonite output is expected to grow by about 6-8 percent year-on-year for the next 4 years – based on a local demand increase of about 5 percent and a significant growth in exports. Growth will be focused primarily on the foundry and pelletising industries, particularly in the short and medium term (with market saturation in the next 4 years). Strong growth is expected as: 1) all ferrochrome plants are now utilizing Outokumpu- and Premus-type pelletising, 2) most ferrochrome producers have approved plant and furnace capacity expansions (which includes the addition of 7 pelletising plants), and 3) two new plants will be built, namely the Tata Ferrochrome plant and International Ferrometals Plant (construction to commence from 2006 onwards).

Strong growth is expected in the foundry industry, particularly in green sand moulding. Car exports are set to increase significantly with the awarding of large international contracts to local automobile manufacturers. This will result in higher throughput at large-scale foundries and thus a proportional increase in bentonite consumption.

The expansion of new niche markets in the following applications: civil/ environmental (particularly import replacements, water retention and treatment), medicinal, aquamarine, nano-plastics, fibre technologies, pulp and paper manufacturing (retention/ drainage aids) and composite material manufacturing for dye-removal, wine-clarifying and civil applications will ensure real sales growth over the next 5-10 years. However, the single largest deterrent to significant real growth in niche markets is the “consumer mindset” and “ignorance”.

The consistency, quality and swelling properties of South African bentonites are favourable for exports, although the location of local producers in terms of world markets and the low Rand-dollar exchange rate makes export initiatives uneconomical at present. However, exports to the Middle East, Far East, South American and Europe as well as the SADC countries can be expected to grow by at least 9 percent year-on-year (depending on GDP, industrialization and forex rate of neighbouring and partner countries).

All local bentonite companies have benefited through several cost-cutting exercises: focusing on markets and customer needs instead of products, streamlining internal structures and creating new key account management structures. All processes from order intake to purchasing, production, logistics and after-sales service, have or are currently being tailored to customer needs.

Bentonite recycling initiatives include the recovery of spent foundry sands (through the reclamation of bentonite moulding sands) for use in ceramic and tile manufacture; and the use of lightweight aggregate (pelletised products from the sintering of fly ashes with bentonite or pulverized coal) in construction. Improved efficiencies in green sand moulding may result in less bentonite been consumed per manufactured article than in previous years.

Several opportunities exist for small-scale mining in this field – either through partnership or the exploitation of unworked, localized deposits. However, technological advancements, streamlining of operations and the limited sized of this sector have made it almost impossible for new entrants to break into the market.

B. Talc & Pyrophyllite

1. Introduction

Talc, a hydrated magnesium silicate, seems to have been derived from the Arabic word "*talq*", meaning mica. Like mica, talc can be found in sheet-like masses, be foliated or have a scaly appearance, and has perfect basal cleavage that allows it to split into wavy, flexible, non-elastic flakes.

Pyrophyllite is a hydrous aluminium silicate with a structure similar to talc; the mineral name pyrophyllite originated from the Greek *pyro*, meaning fire, *phyllo* - leaf and *lithos* - stone; in essence it refers to the effect of heat separating the laminae in foliated varieties. The similarities of talc and pyrophyllite (regarding chemical, physical and optical properties and applications) have made it necessary to combine the two minerals for this report (Diagram 1).

Talc varies in colour, but is most commonly white, pale grey or green. Other talc characteristics include its softness, pearly lustre and greasy feel. Pure, massive talc hosting orebodies are often referred to as steatite. The industrial importance of talc is based on its intrinsic softness, smoothness, lubricative, chemical inertness, high oil absorption, low thermal and electrical conductivity, high melting point, low thermal expansion and most importantly, its whiteness (see *Addendum 6*).

Pyrophyllite shares the above properties, but differs by being slightly harder and substantially more refractory (i.e. fuses at a higher temperature). These intrinsic properties are utilized in white ware, electrical switchboards, cosmetic applications (talcum powder), as a lubricant, as filler in paint and paper manufacture, as refractory and in ceramics (see *Addendum 7*).

Talc's crystal structure, bonding, cleavage, hardness, density and optical properties are similar to those of pyrophyllite. Talc is hydrophobic (does not attract water), however, it serves as a good adsorbent for organics and is widely used in talcum powders. Most economically important talc deposits formed either by the alteration of mafic and ultramafic rocks or by the metamorphism (contact or regional) of dolomitic sediments. In South Africa, commercial-grade pyrophyllite is prevalent as massive deposits, particularly in the Ottosdal area (North West province).

In 2003, there were 5 talc and pyrophyllite mines in South Africa (all with on-site crushers and/ or plants). These alumino-silicates are mined by opencast methods and extracted as blocks, lumps, cobbles and pebbles. Talc is extracted as a by-product of feldspar/ pegmatite mining. Talc can also be produced synthetically.

Depending on the nature of the orebody, talc and pyrophyllite lumps are either 1) crushed and sized to cobbles, pebbles and finer grades or 2) through hydraulic hammer and circular saws, cut into slabs and blocks for further processing; it is then sold in various crude or processed forms, but most often milled, reconstituted or in block form. Major markets (in descending order of magnitude) are paint, paper, synthetic diamond manufacture, resin filler and refractories.

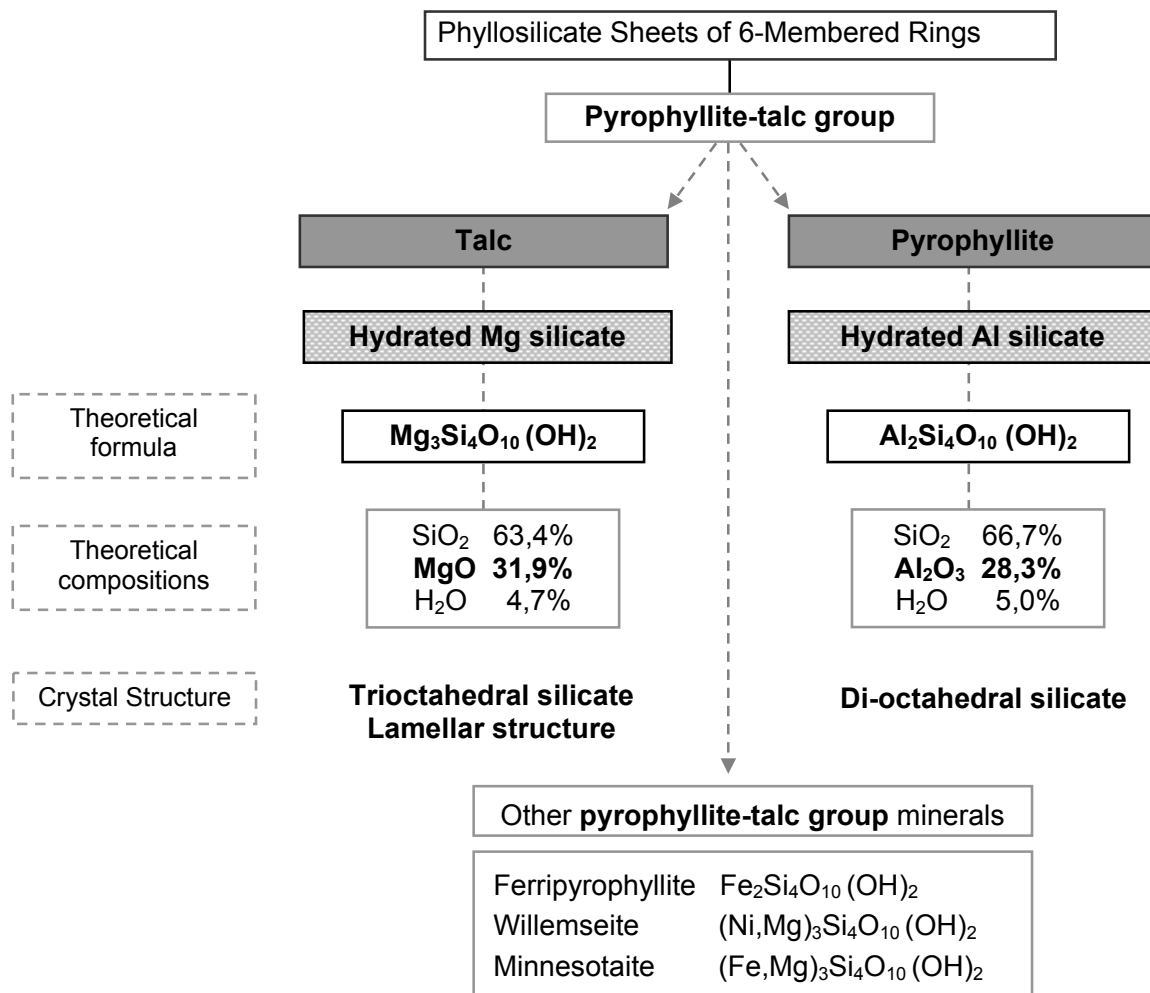
The characteristics of associated minerals can influence pyrophyllite's commercial properties, e.g. quartz contributes abrasiveness, kyanite refractoriness, and sericite lubricity. In addition, pyrophyllite occurs in several forms including fine-grained with foliated laminae and platy cleavage (used in whiteware, fillers), massive spherulitic aggregates of small crystals (refractories), and radiating needle-like crystals (fillers, whiteware and minor refractories).

South African pyrophyllite deposits have been labelled A-grade (one of only a few in the world). Raw material from these deposits has the following characteristics: excellent thermal shock resistance, extremely low thermal expansion, excellent chemical resistance, high mechanical strength and high melting point (1 600°C).

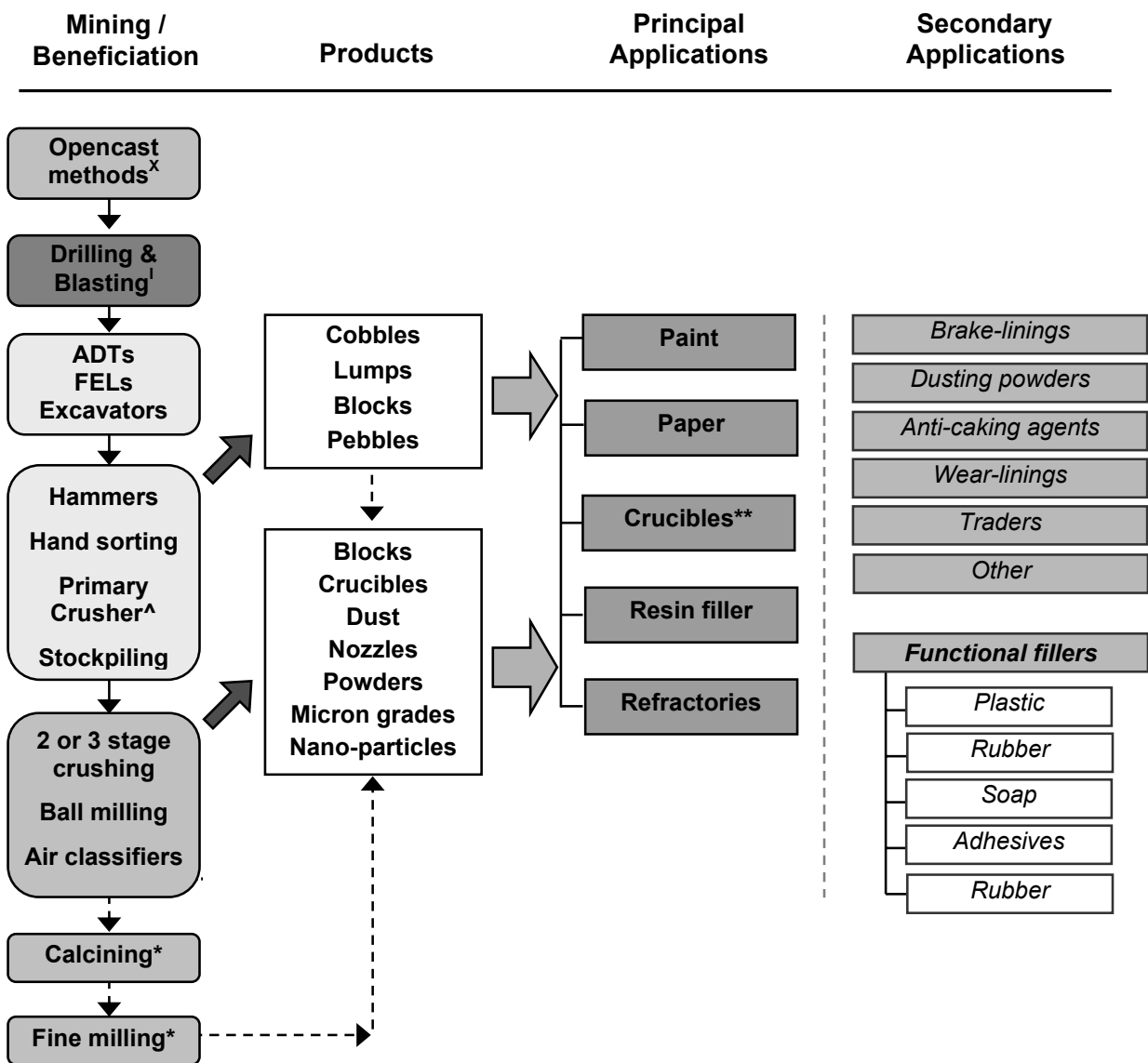
Table 1: Commercial pyrophyllite terminology

	Brazilian equivalent	Japanese & Korean equivalent	South African equivalent
Pyrophyllite	<i>Agalmatolite</i>	<i>Roseki</i>	<i>Wonderstone</i>
Assemblage composition	Pyrophyllite, muscovite, diaspore, kyanite & quartz	Pyrophyllite, sericite, kaolinite & quartz	Pyrophyllite, rutile, chloritoid & epidote

Diagram 1: Pyrophyllite and talc nomenclature and classification

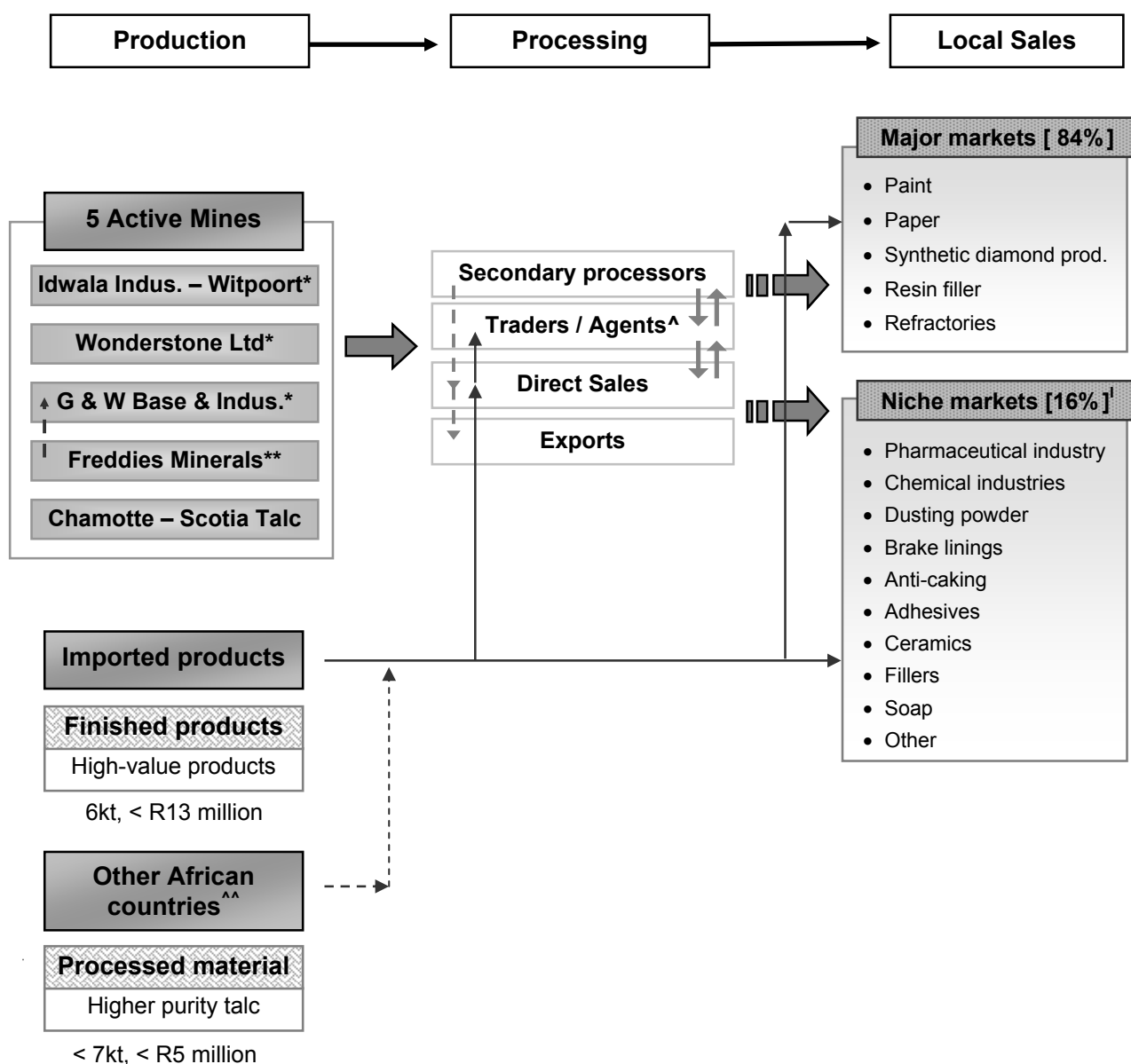


2. Industry Flowchart



- Notes:
- ^x Scotia Talc is the only underground operation
 - ^l Impact hammers & diamond circular saws used at Wonderstone; at Scotia Talc hoppers are used to transport ore material to the surface
 - [^] Block cutting, secondary & tertiary crushing, calcining, pressing and final product manufacture done on-site at Wonderstone, directly after drilling & blasting.
 - ^{*} Optional step at most operations, particle size < 10µm
 - ^{**} Crucibles used in synthetic diamond manufacture.

3. Industry and company structure^{II}



Notes: ^{II} As at 31 December 2004

* Pyrophyllite producers

** Freddies Minerals sells talc to G & W Base & Industrial

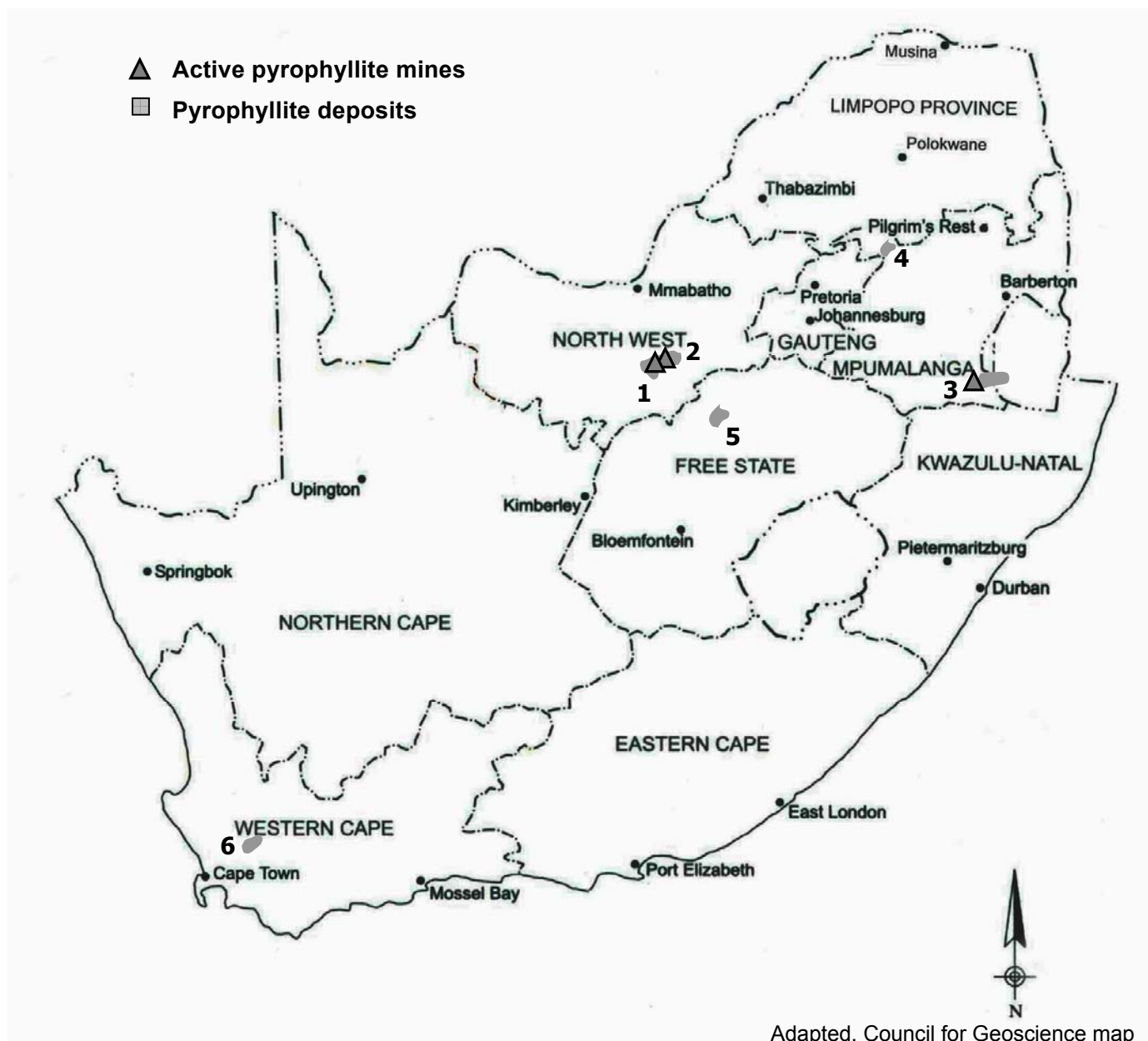
^{^^} No accurate information is available

[^] Sells these products without any significant value addition or further beneficiation, although most traders do contract milling – no accurate information is available

[†] Includes traders (3,7%)

4. Raw Materials

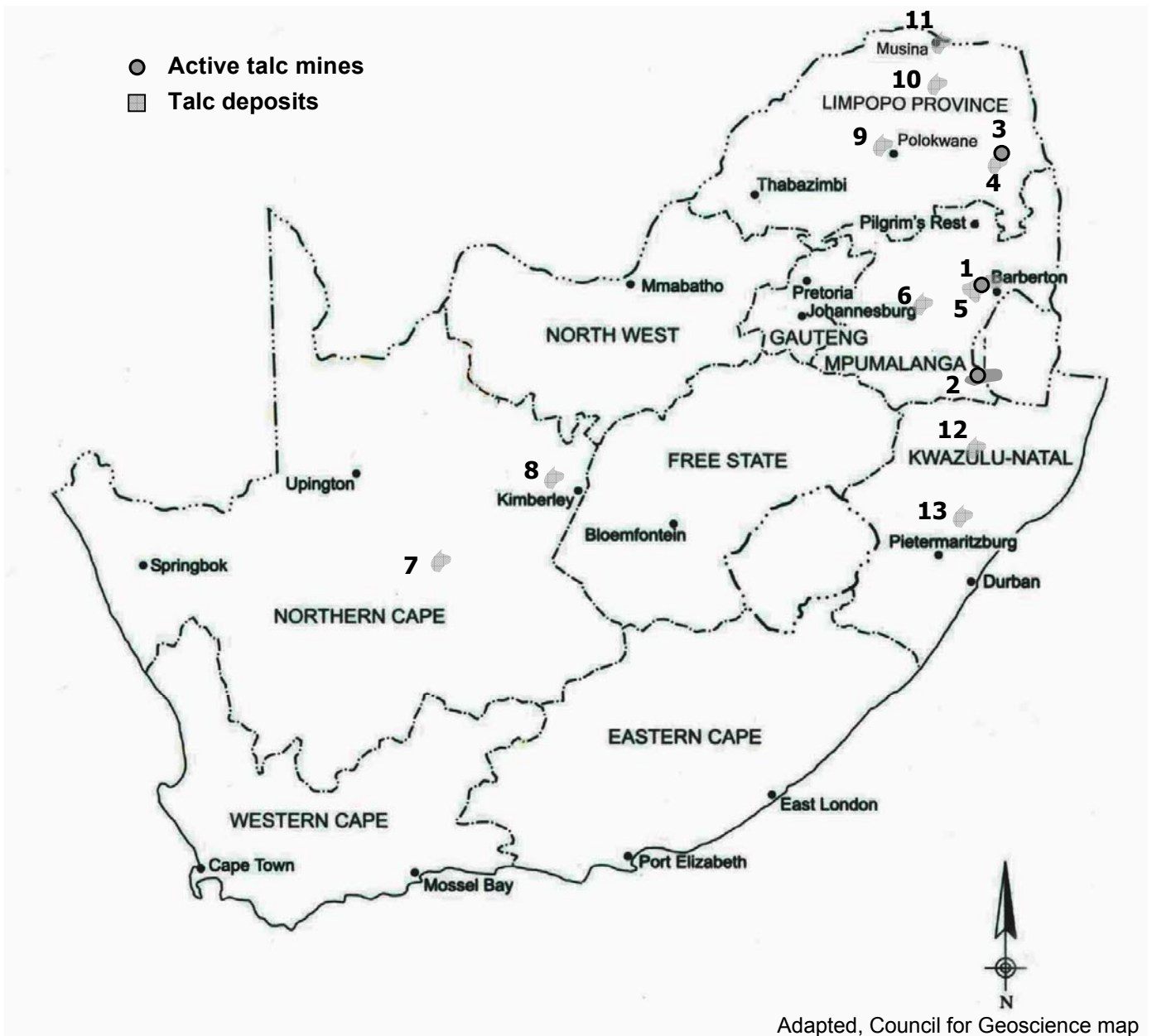
Diagram 2: Simplified map of South Africa's major pyrophyllite mines and deposits



Adapted, Council for Geoscience map

Deposit	Nearest district / town and mine ownership
1	Wonderstone Mine, Ottosdal, Assore Limited, active mine
2	Witpoort Quarry, Ottosdal, Idwala Industrial Minerals, active mine
3	Masala Mine, Piet Retief, G & W Base & Industrial Minerals, active mine
4	Groblersdal deposit
5	Odendaalsrus-Welkom deposit
6	Waihoek deposit, near Worcester

Diagram 3: Simplified map of South Africa's major talc mines and deposits



Adapted, Council for Geoscience map

Deposit	Nearest district / town and mine ownership		
1	Scotia Talc Mine, Barberton, Chamotte Holdings, active mine		
2	Masala Mine, Piet Retief, G & W Base & Industrial Minerals, active mine		
3	Morelag Mine, Phalaborwa, Freddie's Minerals, active mine		
4	Gelletich Mine, Phalaborwa, Micaceous Minerals, closed mine		
5	Barberton-Nelspruit deposit(s)	10	Soutpansberg deposit
6	Carolina deposit	11	Messina deposit
7	Prieska deposit	12	Nqutu deposit
8	Barkley-West deposit	13	Tugela Valley deposit
9	Polokwane deposit		

Pyrophyllite deposits are considered to be either hydrothermal or metamorphic. Hydrothermal deposits are the most common type and form by hydrothermal or metasomatic alteration of feldspars in acid volcanic rocks. The hydrothermal fluids move along shear zones and faults, and gradually alter the alumina-rich parent rock to pyrophyllite. Smectite clays might develop as an intermediary stage in pyrophyllite evolution. Metamorphic deposits are less common and occur as pyrophyllite schists, often associated with metamorphosed volcanics.

Pyrophyllite forms during low- to medium-grade metamorphism of alumina-rich rocks, with volcanic ash horizons being most susceptible. Minerals commonly associated with pyrophyllite include kaolinite, alunite, quartz, sericite, montmorillonite, diaspore and corundum. In South Africa, the Ottosdal A-grade deposits are associated with the altered, decomposed felsic volcanic ashes from within the Dominion Rhyolites, which underlie the Witwatersrand Supergroup. These metamorphosed rocks have experienced significant stresses and are heavily jointed with layers dipping at 85°C. Minor oxide intrusions, weathering and jointing has contributed to low yields/recovery grades for block-cut pyrophyllite.

Most economically important talc deposits formed either by the alteration of mafic and ultramafic rocks or by the metamorphism (contact or regional) of dolomitic sediments. Talc deposits derived from mafic or ultramafic rocks involve an initial *in-situ* chemical alteration of the magnesium silicates (e.g. pyroxenes, amphiboles, olivine) to serpentine, after which steatitisation results in the formation of talc. Minerals associated with this style of talc mineralisation include chlorite, magnesite and serpentine.

Talc formed by regional or contact metamorphism of dolomitic sediments requires the addition of silica and minor amounts of water. These are sourced from associated siliceous sediments (in regional metamorphism), or from late-stage hydrothermal fluids related to granitic plutons (contact metamorphism). Associated minerals include tremolite, chlorite, diopside, serpentine, quartz, calcite and dolomite.

Talc deposits are classified according to the parent rock from which they are derived. There are four types of talc deposits, namely talc derived from:

- ▶ **Magnesium carbonates.** About 50% of the world's talc production is associated with this type of deposit, occurring in ancient metamorphosed carbonate sequences. This particular talc is generally pure and white.
- ▶ **Serpentines.** This type of deposit contributes about 40% of world talc production. The crude ore is always grey and, to be commercially viable, can be upgraded to improve mineralogy and whiteness (generally by flotation).
- ▶ **Alumino-silicate rocks.** About 10% of world production is mined from these deposits. They are often found in combination with magnesium carbonate deposits. The crude ore is generally grey due to the presence of chlorite – no ore upgrading is generally needed as chlorite performs adequately in the applications of interest.
- ▶ **Magnesium sedimentary deposits.** Talc is formed by direct transformation of magnesium clays. No such deposit is currently mined.

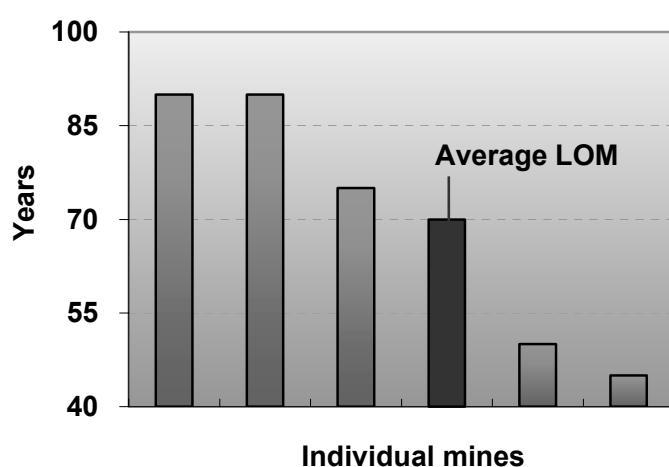
This wide diversity of origins and types of deposits naturally gives rise to a wide variety of talc ores and product grades, which differ according to their mineralogical composition, colour and crystalline structure (micro-crystalline or lamellar).

5. Reserves and Resources

Product development in reconstituted powders and products, particularly in the pyrophyllite industry, has increased significantly in the last 3 years. This has unlocked recovery grades from an initial 10% up to 92% at present – the average yield per mine is about 75%.

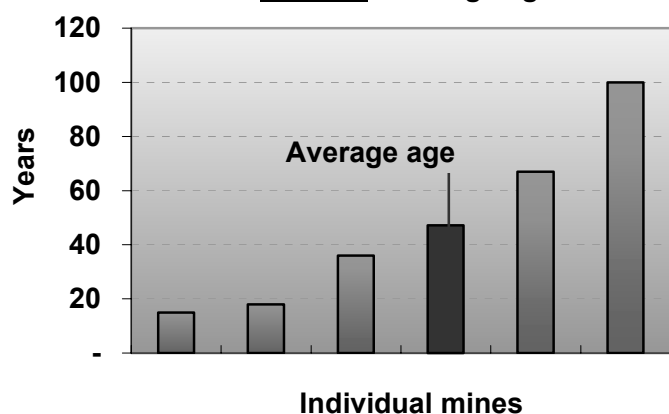
Talc and pyrophyllite deposits, collectively have a reserve base of about 36 Mt, although most operations have orebodies of <2Mt. Most mining operations have LOM plans of between 45 and 90 years (Graph 1). The average age of talc and pyrophyllite mines in South Africa is 47.2 years (Graph 2). Two operations are looking at recovering high-grade talc and pyrophyllite from tailings dams.

Graph 1: LOM of talc & pyrophyllite mines, 2004



Reserves of pyrophyllite and talc are adequate in the long-term, thus most operations have LOM plans for at least 45 years. The average LOM is 70 years. The orebodies are extensive – some have been exploited since the early 1900's and 1930's.

Graph 2: Average age of talc & pyrophyllite mines, 2004



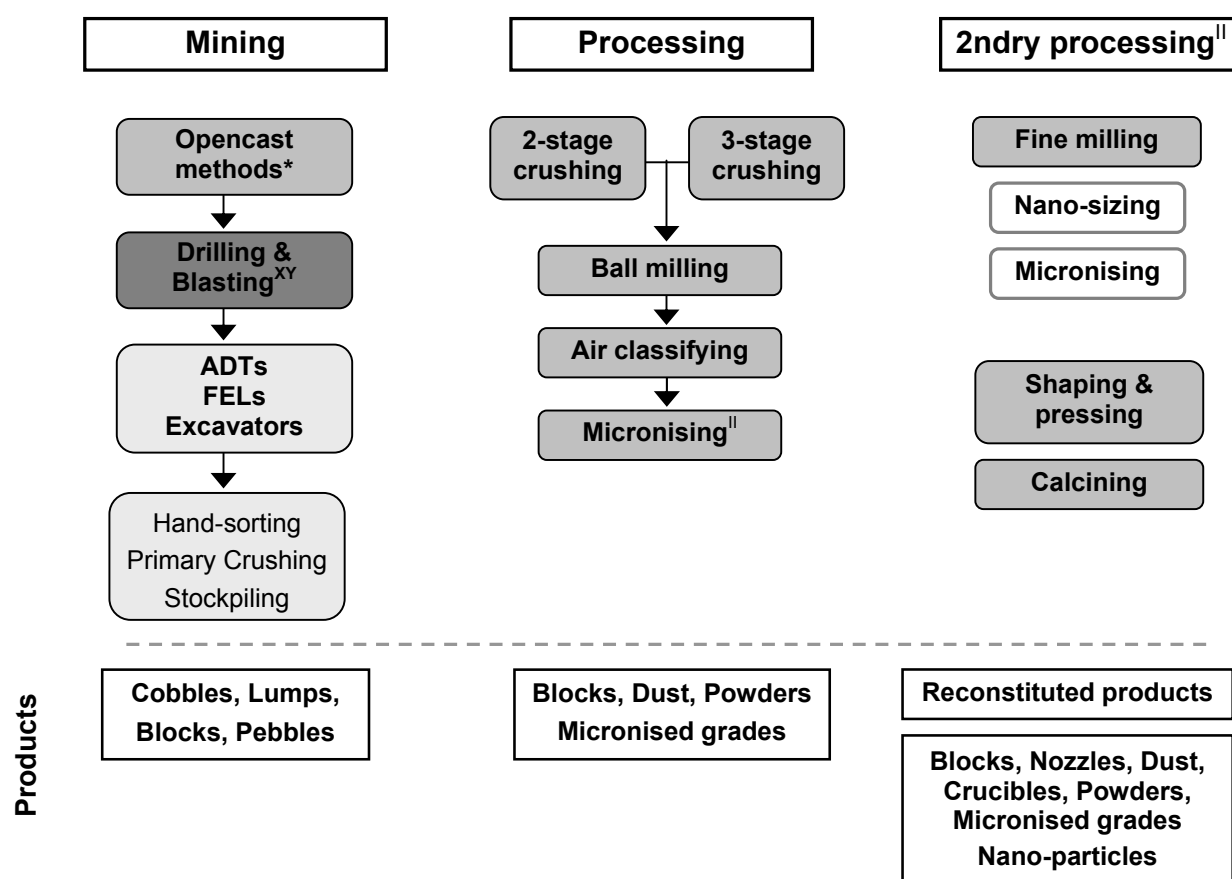
All talc and pyrophyllite mines have been operating for at least 20 years, the oldest being Scotia Talc at 100 years. The average mine age is 47.2 years.

6. Pit and Plant Processing

Talc and pyrophyllite mines in South Africa are generally small to medium-sized opencast operations – Scotia Talc Mine near Barberton being the only underground talc mine. At all these alumino-silicate operations, grade varies considerably and selective mining is practised. E.g. At Freddie's Minerals, talc is mined as a by-product of feldspar; a sulphuric acid test applied to the wall-face determines if the talc is of suitable quality for further processing.

Further beneficiation includes hand-sorting, fine milling and/ or fine milling and air classification (Diagram 4). One particular operation uses impact hammers and diamond circular saws in ore extraction, with further value-addition that includes micronising, calcining and pressing. Pyrophyllite producers described their plant technology as 'leading edge', whilst talc producers described their technologies as either 'old' or 'current'. Most mining concerns run a 12-16 hour pit operation whilst plant operations run for at least 16-24 hours a day.

Diagram 4: Pit and plant processing flow diagram



- Notes:
- * Scotia Talc is the only underground operation
 - X Impact hammers & diamond circular saws used at Wonderstone; at Scotia Talc golowans/ hoppers are used to transport ore material to the surface.
 - Y Block cutting, secondary & tertiary crushing, calcining, pressing and final product manufacture done on-site at Wonderstone, directly after drilling & blasting.
 - II Optional step at most operations, average particle size < 10µm

Further beneficiation, through flotation and magnetic and gravity separation is possible, but unprofitable in the South African context as markets are too small and revenue generation too low. Most R & D is done on-site at dedicated research laboratories (at the plant itself or head office), one company contracts out all research to international laboratories and another has intellectual property/ technology transfer agreements in place with local and foreign companies.

Some companies have invested significant amounts into on-site secondary and tertiary processing facilities, so as to produce high-end value-added products; e.g. Wonderstone Limited has invested several millions of Rand in equipment to exploit the potential of reconstituted and powder-based pyrophyllite. Technological purchases include several uniaxial presses, an isostatic wet bag press, a shear plough (high-energy mixer/ granulator), additional calcining units and electric furnaces. Synthetic diamond manufacture will also be done on-site within the next year.

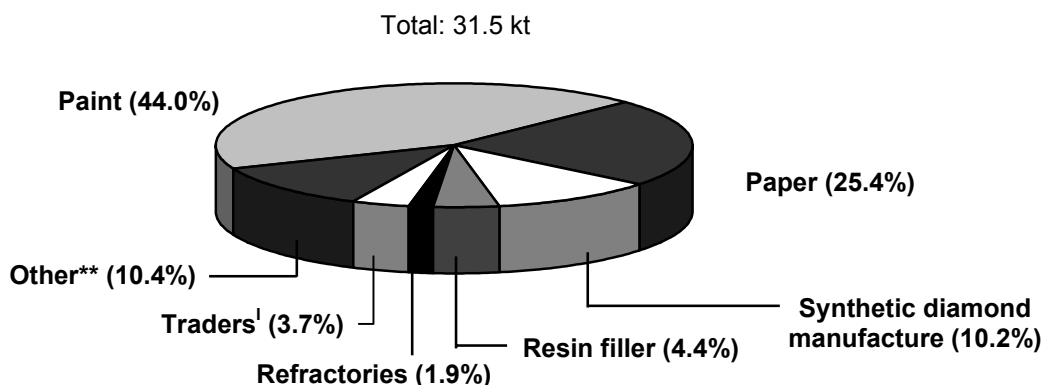
These plant acquisitions have allowed Wonderstone Limited to improve consistencies in powder mixes, expand their product ranges and to enter new markets such as brake lining products, crucible block manufacturing from powders, and chromic acid purification pots.

7. Product Overview and Applications

A host of optical- (e.g. brightness), refractory- (firing temperature, thermal stability and thermal conductivity), chemical- (purity, LOI, inertness, affinity to organic chemicals) and physical properties (particle size distribution, fineness, lamellar texture, bulk density, whiteness) determine which markets talc and pyrophyllite are used in. Transport costs can be as much as 65% of the final product price, or as low as 1% with high-value products.

In South Africa, pyrophyllite and talc compete and/or substitute each other as functional fillers in paper, ceramics and paint. South Africa's A-grade pyrophyllite materials are however superior in refractory applications (talc fluxes upon heating). At 1 200°C, pyrophyllite's Mohs' hardness increases from 1-2 to 7-8, with a melting temperature of 1 600°C. Graph 3 illustrates key talc and pyrophyllite markets sectors.

Graph 3: Primary markets, by volume*, for all talc and pyrophyllite products, 2003



- Notes:
- * Includes SARS imports of 6kt
 - ^I Agents or secondary processors that sell into mineral filler markets
 - ^{**} Includes adhesives (1,0%), soap (1,0%), brake linings (1,0%), dusting powders (0,2%) and anti-caking agents (0,2%).

7.1 Paint

The lamellar particle shape of talc improves opacity by spacing the primary pigments (see *Addendum 10*) in paint coatings. Micronised talc is used in interior and exterior architectural coatings to:

- ▶ Improve opacity, tint strength, durability and heat resistance,
- ▶ Enhance viscosity and sag resistance,
- ▶ Control gloss and sheen, and
- ▶ Reduce cracking.

In 2003, about 250 million litres of paint (worth R3,3 billion) were produced in South Africa. Markets are split up into 5 major sectors (Table 2A). The decorative market (DIY, retail, construction, etc) comprises the following paints: primers, undercoats, PVA, acrylics, off-gloss paints and gloss enamels; it is also the largest consumer of mineral fillers in the paint market. These paints contain varying amounts of mineral and/or functional fillers (Table 2B).

Table 2: A) Paint consumer market B) Mineral composition of paint

A	Million litres	Markets
	130	Decorative
	18	Automobile
	30	Heavy-duty [#]
	34	Industrial paints [^]
	40	Solvent exports
	~250	Total market

B	Percentage of total paint weight (in %)	Mineral / functional filler
	< 0.3	Bentonite
	5-20	Talc*
	5-25	Kaolin*
	20-50	GCC*
	0-5	Pyrophyllite*
	< 10	Barium sulphate
	< 10	Pyrites

- Notes:
- # Used as an anti-corrosive coating for pylons & large structures
 - [^] Road marking, surface-, sheet-, appliance- and caravan coatings
 - * Not used in gloss enamel paints

Acrylics and PVA paints comprise about 60-70% of the decorative market. Varying amounts of talc (<10% per volume) and bentonite (<0,3%) are used. GCC is the main mineral filler in primers, whilst gloss enamels contain the least clay fillers. Industrial and automobile coats contain almost no kaolin or pyrophyllite.

The following trends have been noted in the paint industry:

- ▶ There has been a strong move away from 7-8 fillers to 2-3 fillers. High-quality fillers, such as GCC and upgraded, calcined kaolins have cumulatively replaced up to half of the solvents and whitening pigments normally used in paint. Talc suppliers have been negatively affected by these substitutions.
- ▶ There has been a move away from solvent-based to water-based paints (due to environmental concerns), and
- ▶ Paint coatings have become 'thinner' – new technologies have allowed for coatings to be 1-5µm thick, as opposed to 10µm several years ago. Thus, less paint is required per unit surface area.

7.2 Paper Manufacture

The second largest market for talc and pyrophyllite products is the paper industry. Low-value products are used in filler applications, whilst the high-value products (which are calcined and micronised) are used as paper coating agents (see *Addendum 11*). Currently, only one locally produced, calcined pyrophyllite is suitable for pitch control applications. Tests are being conducted on its suitability for paper coating applications. Only imported talc is used in paper manufacture. GCCs have replaced all fine and base paper fillers in the paper market, with volumes exceeding 70kt per annum.

Talc and pyrophyllite products improve:

- ▶ Mattness,
- ▶ Opacity,
- ▶ Paper lustre,
- ▶ Pitch control,
- ▶ Printability, and
- ▶ Printing ink absorption

Coating pigments are used in rotogravure (coated and uncoated) and offset. Talc improves printability and reduces surface friction by enveloping sticky ink particles and thus preventing any ink agglomeration or deposition. The use of talc provides substantial improvements in productivity at paper mills and printing houses. Talc is ideally suited as a coating agent, primarily because of its plate-like nature, high brightness, gloss, smoothness and reduced friction.

7.3 Refractories

Talc is widely used to make cordierite bodies which serve as refractory material up to 1 460°C. No local talcs are used in refractory applications. Pyrophyllite gives permanent expansion on firing temperature, excellent thermal stability, minimal deformation under load at high temperatures, low bulk density, low thermal conductivity and good resistance to corrosion by molten metals and basic slags (such as in the iron and steel industry). Both refractory-grade talc and pyrophyllite are used in the manufacture of insulating firebrick, stiff plastic refractory composites, castables, gunning mixes, kiln car refractories and furniture, refractory mortars, chute linings, wear-resistant and anti-corrosive linings, prototyping, plasma cutting and mould coatings.

7.3.1 Synthetic diamond manufacture

The need for synthetic diamonds was borne out of the need to control the shape of diamonds for use in cutting tools. Graphite is placed in a pyrophyllite vessel together with an alloy of cobalt that acts as a solvent at high temperatures. The vessel is placed inside a block of tungsten carbide. High pressures of 55 kbar (1 million psi) are applied to the tungsten carbide block which are transmitted to the vessel and an electric current is passed through the vessel to raise the temperature to 1 400°C. The graphite 'seeds' are liquefied and subsequently crystallize into diamonds with diameters of up to 0,5mm. Pyrophyllite's unique characteristics such as low electrical and thermal conductivity and a rise in melting point with an increase in pressure make it an efficient crucible in synthetic diamond manufacture.

7.4 Resin Fillers

The addition of fine and ultra-fine talc to resins reduces shrinkage and improves smoothness, opacity, abrasion-, temperature- and abrasion resistance in epoxy, urethane and polyester

systems. The use of talc increases stiffness and weight of a cured system. Talc can also be used to fill voids or as a faring compound. Talc can be used to lubricate moulds and prevent surfaces from sticking together; and it retains its lubricity at high temperatures.

Talc is also one of the lowest cost fillers for thickening polyester and epoxy resins. As an additive with activated epoxy resin, talc increases bulk, prevents sagging and can be used to change resin colour. Talc can also be used in joint compounds and urethane sealants and can be added to butyl caulks, acrylic sealants and dry wall compounds.

Resin filler content may vary, although industry standards are 1 part talc to 1 part resin for a thick, but pourable liquid that is suitable for potting; and 2 parts talc to 1 part resin for a light paste consistency.

7.5 Other Filler Uses

Rubber and plastic technology: Talc is widely used as reinforcing or functional filler in rubber and plastic industries. In rubber it provides insulation strength to electrical cables, acts as a processing aid (particularly in wire, cable and tyre manufacture) and enhances the permeability of stoppers and membranes. In plastics, talc improves quality and ageing resistance. Talc is used in polypropylene for automotive parts (bonnet, dashboard, interior- and exterior trim), household appliances and white goods. Talc additives in polypropylene improve stiffness and dimensional stability. Micronised talc is used for linear low-density polyethylene anti-blocking and as a nucleating agent in semi-crystalline polymers. In food packaging, talc is ideal as reinforcing filler.

Oil and paints technologies: Talc is used as a white pigment and/or filler material in paints. It possesses good oil absorbing capacity and prevents ageing and cracking of paints.

Textile industries: Talc, as functional filler in textiles, increases both colour brightness and intensity, strengthens product density and improves resistance to heat, acids and bases.

7.6 Ceramics

Electrical Ceramic Ware: Talc is used for making electrical porcelain and electrical insulating products. It improves their mechanical strength and reduces shrinkage during sudden change of temperature leading to the improvement in the thermal shock resistance. Steatite bodies, which contain 60-80% of talc, have high mechanical strength and low dielectric loss. It is used in the electronic industry, radio industry, aerial equipment, sockets and condenser plates, catalyst supports and kiln furniture. Pyrophyllite lowers the firing temperature, suppresses deformation and cracking, increases whiteness, lowers firing shrinkage and improves thermal shock resistance.

Dinner Ware Bodies: Talc can be used as a low-cost source of magnesia, it increases thermal expansion and decreases the moisture expansion in low temperature bodies and thus suppresses the crazing problem of the glaze in dinnerware bodies. It also produces translucency in fired ware and increases its durability. Talc is used in semi-vitreous china firing between 1 190 - 1 230°C. As a flux in ceramics, talc helps produce a denser body while using lower firing temperatures.

Wall Tiles and Glazes: Calcium-rich talc (i.e. thermolytic talc) is extensively used in wall tiles bodies. In wall tile bodies, talc and pyrophyllite delays the onset of crazing and reduces thermal expansion and warpage. In the manufacture of high-temperature glazes, talc is used as a brown colouring agent – the glaze is prepared by adding 15% talc to an opaque glaze.

Roofing Materials: Low-quality ground talc is widely used to produce various kinds of roofing materials such as asphalt felts, sealing and waterproof materials due to the hydrophobic nature of talc.

7.7 Organic, Pharmaceutical & Cosmetic Industries

Due to its organophilic nature, talc is widely used as an absorbent material in various organic industries; these include cosmetic, medicinal and insecticide carrier applications. Since the banning of DDT mixtures, insecticide consumption (and indirectly talc consumption) has decreased significantly. In the cosmetics and pharmaceutical industry, the chemical composition of talc is not critical (assuming low lead and arsenic values are maintained), however the presence of sericite is preferred to more abrasive quartz; and, the occurrence of platy pyrophyllite is preferred to more massive varieties. South Africa imports cosmetic-grade talc.

7.8 Brake Linings

Rapid developments over the past few years within the automotive and locomotive industries have resulted in a growing demand for high-quality friction materials. Brake linings must adhere to the following prerequisites: a high level of energy absorption, high brake efficiencies within a wide temperature range, durability and absence of noise. Through much R & D, reconstituted pyrophyllite powders are now a major component of high-performance brake pads.

The extreme consistency of local pyrophyllite grades provides the predictable nature needed in brake lining development and production. Other economic advantages of pyrophyllite brake linings include its optimal price/ performance ratio with respect to other similarly priced products.

7.9 Animal Food Industries

Talc is used as a coating material in the animal food industry. Talc coatings act as an anti-caking agent, reduce evaporation and prevent water absorption. Talc is also used as a coating in feed bins to absorb the condensation formed on the bin walls.

7.10 Nano-technologies

Surface-modified nanotalc fillers can improve barrier functions and properties, scratch resistance, stiffness, toughness and temperature ranges. Nano-talcs are designed to meet or exceed the capabilities of many engineered thermoplastics, whilst offering the processing advantages that are inherent to polyolefins. Through enhancing the exfoliation process [by separating the stacked, individual leaf-like talc particles], several nano-producers abroad have been able to maximize the performance of the product and make it easy to use. Surface area/ volume ratios are close to 25 times greater than that of normal talc. Nano-talcs require lower processing temperatures, flow easier and cool faster.

Primary markets for this product include mouldings and film applications. Thus consumers can often use less material, improve cycle times, and lower their energy and equipment costs. Other applications include auto-interior and exterior trim; small appliance and power tool housings; packaging liners, containers and closures; pipe, conduit, fittings and fascia used in construction; and fillers in consumer goods such as sealants, adhesives, thermoplastics and other engineered plastics.

7.11 Other Uses

Talc, in the form of soapstone, is used for ornamental purposes. Other uses of pyrophyllite and talc include stucco products, fibreglass, road markings, welding production wallboard, floor coverings, asphalt filler, anti-skid aggregates, white cements, auto-body patching, wear and acid resistant tiles, chromic acid purification pots, butt welding dies and aluminium atomisation nozzles.

Table 3: Typical chemical analysis of pyrophyllite and talc samples

CHEMICAL COMPOSITION	ASSORE – WS raw material ^{II}	IDWALA – Witpoort raw material	G&W Base & Indus., Sericil Talc	Freddies Minerals, cobbled talc	Chamotte Scotia Talc ^O	North Carolina, USA	Som Deniz pyroph. 150µm, Turkey	Talc, Jabalpur district, India [^]	UCI Ultra Pure Talc , USA	Vapi Clay mills, CG talc, India	Vendankur Minerals SW talc ^I , India	Semco Talc - Egypt	Talc, Haicheng, Liaoning, China	Pioneer Talc , West Texas, USA	Talc, South California
SiO ₂	58.0	55.0	65.0	46.5	47.2	75.0	70.0	60.4	61.5	63.0	62.7	62.1	60.0	63.6	62.3
Al ₂ O ₃	29.5	34.0	25.0	6.4	32.3	19.3	21.5	1.9	1.0	0.8	0.2	0.3	0.3	6.5	1.7
Fe ₂ O ₃	1.3	0.1	<0.2	7.4	4.0	0.8	<0.2	0.2	0.4	0.9	<1.0	0.5	0.3	0.5	1.2
TiO ₂	1.8	1.4	0.5	0.5	na	na	0.5	na	na	na	na	na	na	na	3.1
CaO	<0.5	na	<0.3	1.8	0.8	0.1	0.2	0.1	0.4	0.6	<1.0	na	0.5	1.5	2.0
MgO	na	na	na	28.0	32.3	0.1	0.2	29.2	31.0	32.8	30.3	32.3	31.0	25.9	31.9
(K,Na) ₂ O	<1.0	4.7	5.5	na	na	0.3	-	2.0	na	na	na	na	na	0.2	<0.3
LOI	6-7	5.0	3.5	8.0	20.0	na	5.5	4.0	5.0	0.5	4.4	4.9	7.5	8.7	5.8

Notes: ^{II} WS – Wonderstone Limited raw material
^O Superwhite grade, before drying and calcining
[^] Unprocessed, representative sample for the whole district
^I Super white, micronised grade

8. Supply and Demand

8.1 Supply

Pyrophyllite is supplied to and consumed in a few key regional markets in Asia (< 75%), North America (<9%) and South America (<9%). This "regionalized nature" is a function of:

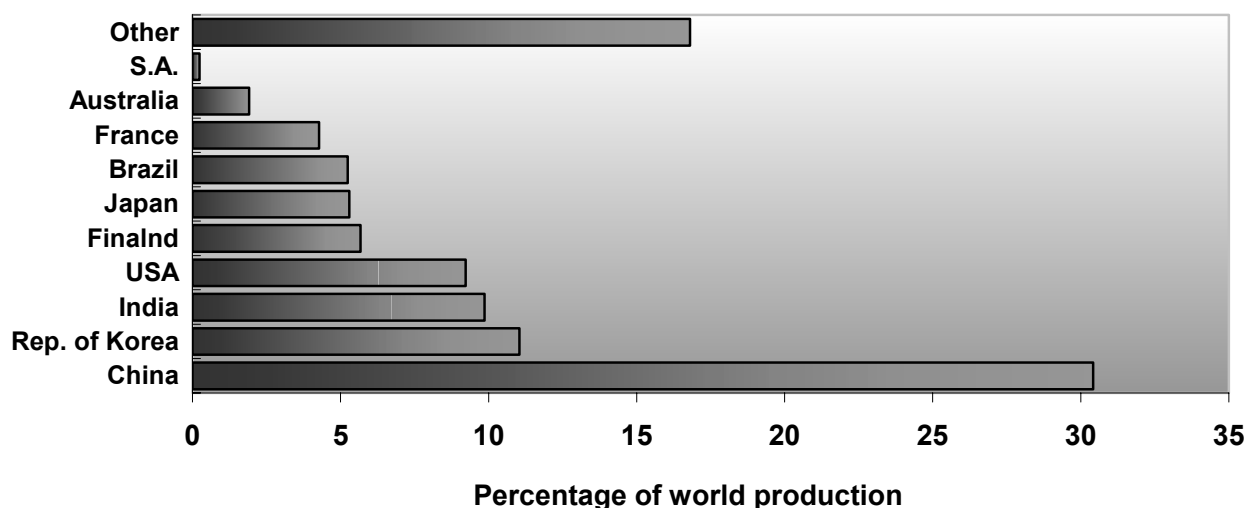
- ▶ The relatively low price of this commodity compared to high freight costs.
- ▶ The need for deposits to be located near shipping facilities and/or manufacturers in order to develop a viable market share,
- ▶ The global availability of many substitute products – minerals that have similar functionality and properties as talc and pyrophyllite are readily available and often cheaper, and
- ▶ Unlike elemental metals, talc and pyrophyllite deposits generally develop their own spectrum of products. One deposit may produce multiple products for multiple end-uses that are exclusive from those products derived from a second, nearby pyrophyllite deposit.

Generally there is no clear definition with respect to "pyrophyllite products". Producers are more inclined to think of themselves in terms of the markets they supply (e.g. refractory or ceramic raw material supplier).

South Africa is ranked 30th in the world in terms of combined talc and pyrophyllite production and contributes 0,2% in volume to global production (BGS, 2002). China, the Republic of Korea, India and the USA account for about 60% of world production (Graph 4). The principal world markets for these aluminosilicates are ceramics, refractories, paint, paper and other functional fillers. Major exporting countries, in descending order of volume, are China, France, USA and the Netherlands, accounting for about 60% of world talc and pyrophyllite exports (Graph 5). The largest importers are Japan, Germany, USA and Italy (Graph 6).

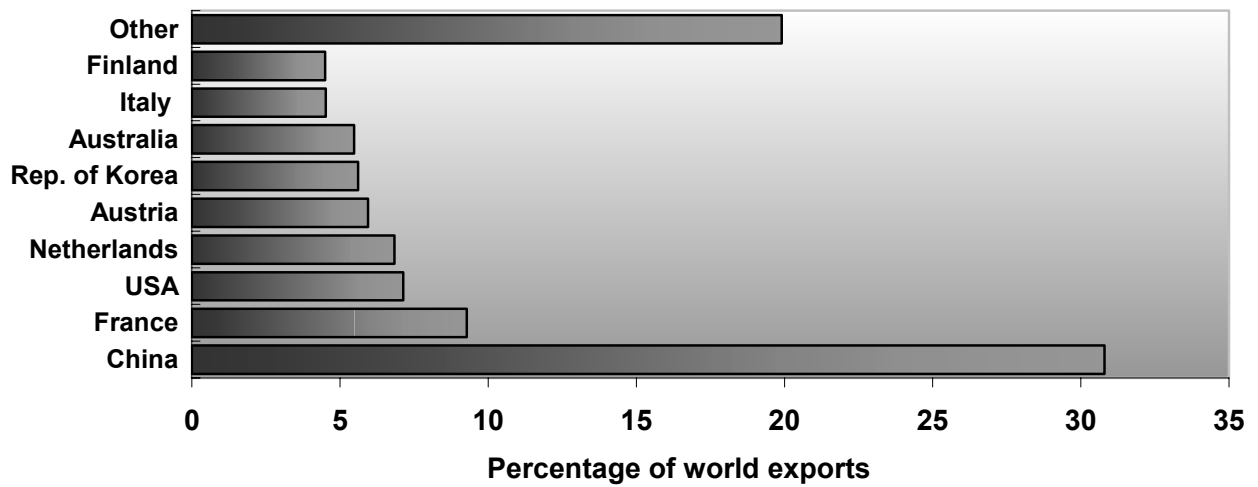
Graph 4: World talc & pyrophyllite production, 2002*

Total: 8.4 Mt



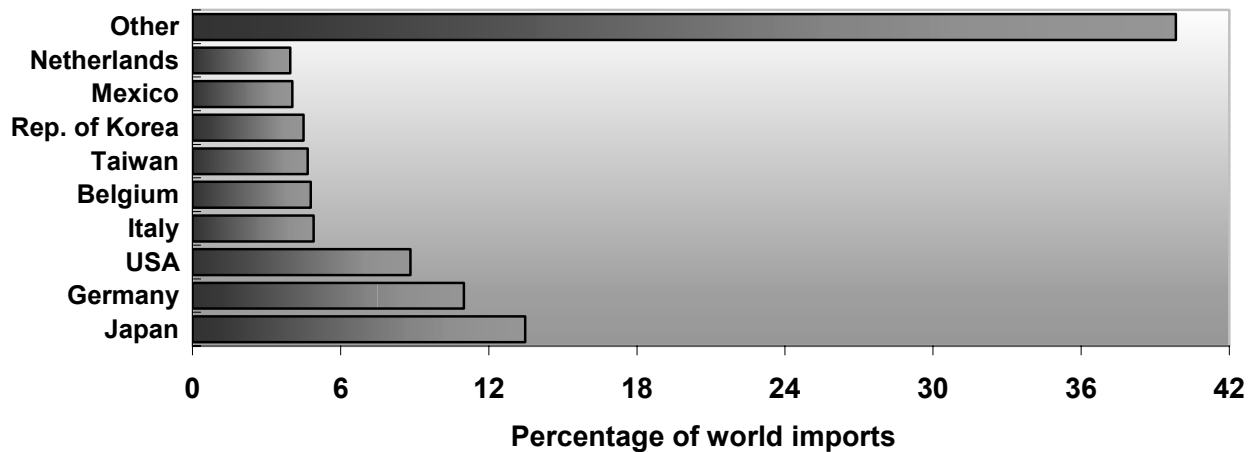
Graph 5: World talc & pyrophyllite exports, 2002⁺

Total: 2.4 Mt



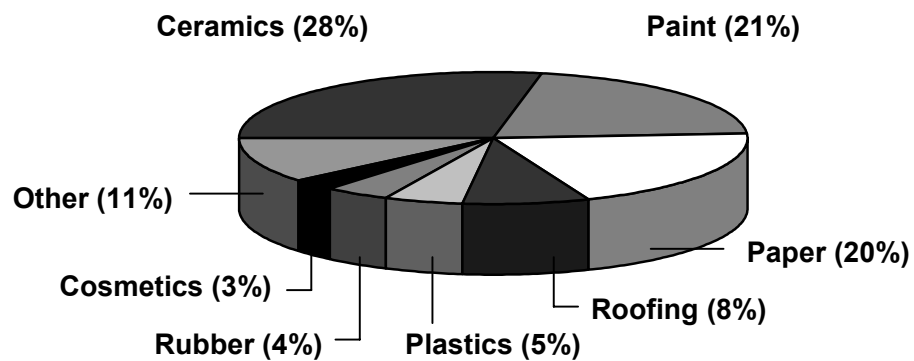
Graph 6: World talc & pyrophyllite imports, 2002

Total: 2.4 Mt



Graph 7: USA talc consumption, 2003

Total: 790 Kt



In 2003, talc and pyrophyllite supplied to the South African market totalled about 31,5 kt of which 81,0 percent (25,5 kt) was from local sources and the balance (6,0 kt) from imports. A small amount (< 1kt) was imported from Zambia.

Talc production centres are limited to the Phalaborwa and Barberton areas, whilst pyrophyllite production is mostly in the Ottosdal district (North West) with minor amounts being extracted in the Piet Retief area (Mpumalanga). More than 60% of talc processing is done on-site. No campaign mining is practised although summer rainfalls (November to February) do hamper production. Plants generally run at about 80-90% of installed capacity, whilst production is significantly lower.

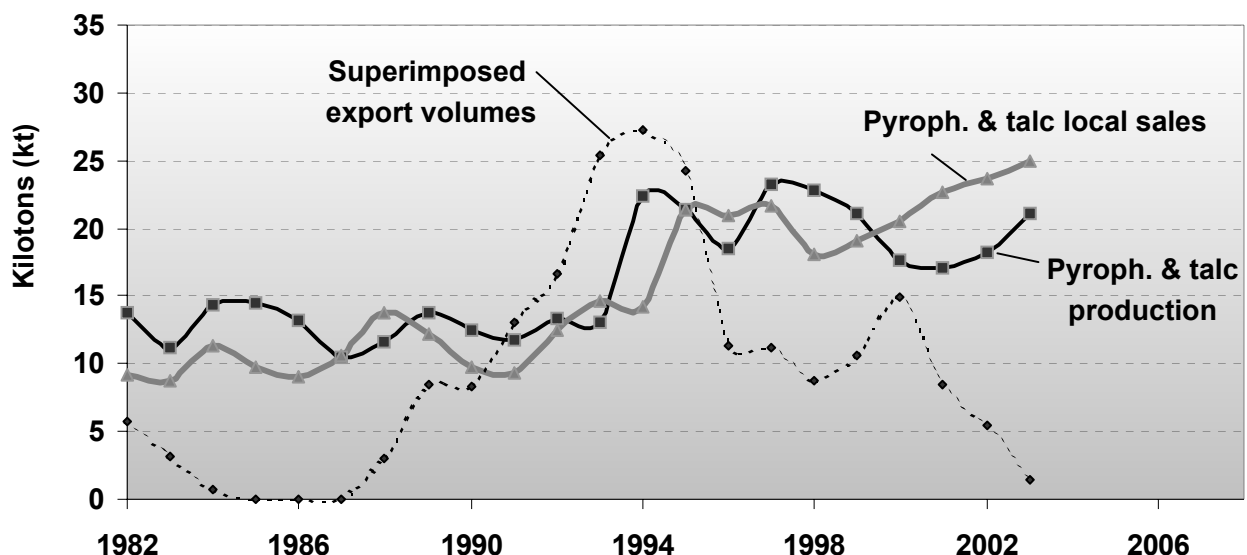
In 2003, production and local sales (by volume) increased by 15,5% and 5,5% respectively (Graph 8). Since 2000, production has increased by 6,4%, although the largest production peaks were attained in 1994 and 1997 (see *Addendum 9*). It is important to note that local sales value and prices are often misleading – most producers sell their products to sister companies (often an on-site or proximally located plant) through internal transfers. Producers are in a position to meet any expected growth in the industry for at least the next 10 years.

8.1.1 Exports & Imports

South Africa exports less than 1,5% of pyrophyllite and talc products. Exports have decreased significantly, particularly from 1994 and from 2000 onwards. This is partly attributed to Wonderstone Ltd which has stopped selling bulk, processed material and through further major value-adding, is now selling finished articles, which are notably more expensive, as export prices have increased appreciably in the last 3 years.

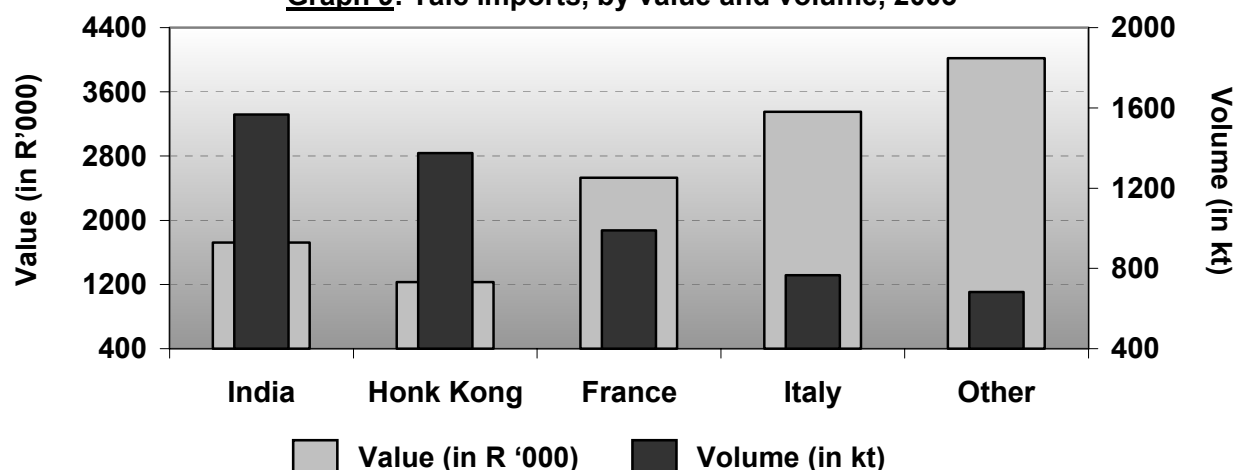
Exports are intimately linked with foreign exchange rates, better-priced international products/substitution, quality and reputation. The majority of producers believe that exports are viable at R7,50/US\$. Exports are shipped to the USA, the Far East and Europe. Local talc products are of low to medium quality and marginally more expensive than similarly-graded, imported talcs.

Graph 8: South Africa's production & local sales of talc & pyrophyllite, 1981-2004



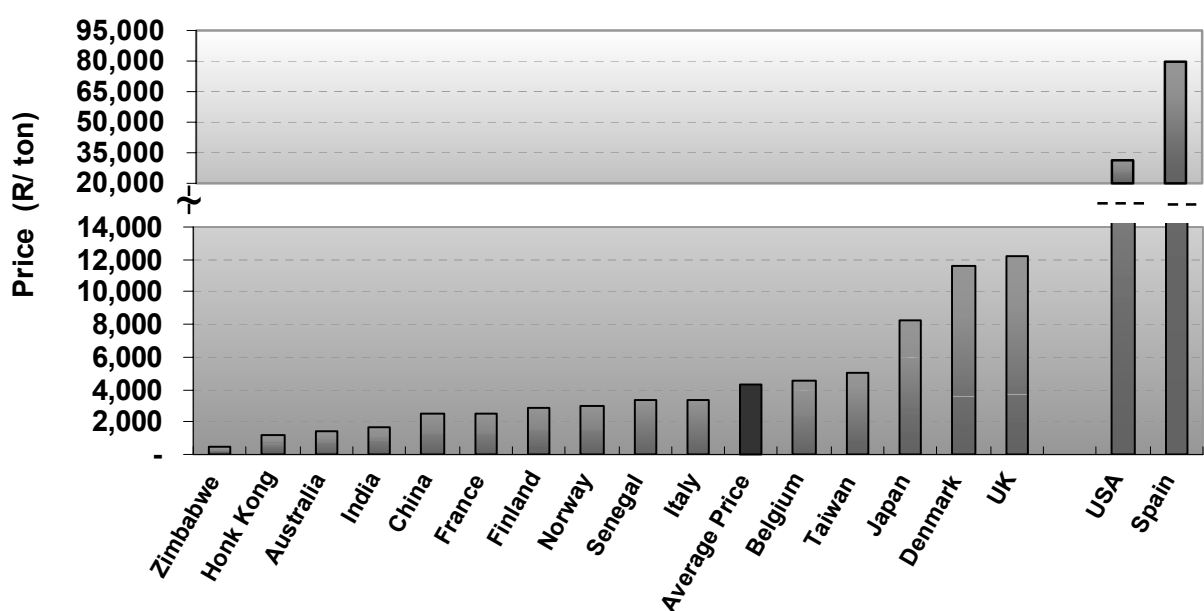
In 2003, major imports, in descending order of magnitude, were from India, Honk Kong, France and Italy. Low-value products were imported from Honk Kong (<R1 232/ ton), whilst the highest-value bulk tonnages (> 0,5kt) were from Italy, priced at R3 354/ ton (Graph 9). Super-grade talc from the USA and Spain fetched prices of R31 000/ ton or more (Graph 10).

Graph 9: Talc imports, by value and volume, 2003



Source: SARS 2004

Graph 10: Average price of imported talc, 2003



Notes: * Price for quality talc products < R13 000/ ton

** Price for superior-grade talc > R13 000/ ton

Source: SARS 2004

8.2 Demand

Local producers satisfy all South Africa's pyrophyllite demand. Local talc grades are used in medium and low-value fillers and talcum powders. Since 1998, local sales volumes have increased by 6,5 % y-o-y. This is exceptional, given that many world talc and pyrophyllite markets have been shrinking over the last decade. Wonderstone Ltd's strategic buy-out of Ceramox has allowed these two entities to combine their mining, processing and manufacturing know-how to provide cost-effective, customised wear solutions – this has given Wonderstone an instant 'foothold' in a market which was previously inaccessible. Similar partnerships with International companies such as Saint-Gobain, have allowed Wonderstone Ltd to share product-knowledge and open up new markets in North America.

In the high-value pyrophyllite market, international competition is intense. These markets include refractories, synthetic diamond manufacture, kiln furniture and wear-linings. Product differentiation, price, consistency, purity, yield rates, tolerance factors, exchange rate fluctuations, turnaround times and ISO compliancy are crucial success factors in this industry. Pyrophyllite sales are also governed by global changes in macro-economies (industrial upturns/ downturns), international regulations and well-marketed cheap substitutes.

Consumer markets have changed drastically in the last 15 years:

- ▶ Local crucible manufacturing as well as pyrophyllite products for the paper market were non-existent 15 - 20 years ago (pyrophyllite substituted Georgian kaolin).
- ▶ Up until 10 years ago, local producers merely supplied local and international buyers with raw material for crucible manufacture. This quickly changed when local producers developed their own pressing systems, as they are now producing both crucibles and synthetic diamonds.
- ▶ Several talc products have progressed from 'basic fillers' to being termed 'specialised or functional fillers', thus opening up markets that were dominated by traditional fillers such as kaolin.
- ▶ In the last 6 years, the closure of all ceramic-producing factories in Lesotho affected talc local sales significantly.

Thus, principal markets that can expect moderate to high growth would include the paint and paper industries, high-quality crucible block manufacturing, wear and acid resistant tiles, specific refractories, drill rig bits, brake linings and filler applications (e.g. plastic and rubber). Strong growth is expected in the construction industry – the knock-on effect would be more paint, resins, adhesives, stucco products and putties required – a predicted growth of 3-4% is expected over the next 3 years.

Niche markets include chromic acid purification pots, personal healthcare products, glass fibre and other civil/ construction applications. Talc and pyrophyllite demand is set to grow at levels significantly higher than that of the macro-economy, at about 5-6% year-on-year.

Niche markets that must still be explored include: asphalt filler, anti-skid products, white cements, auto-body patching and nano-technologies. Nano-technologies, though still in the R & D phase, are expected to grow significantly in the near future – key markets for surface-modified nanotalc fillers would be polyolefins, sealants, adhesives, thermoplastics and other engineered plastics.

Wonderstone Limited is continuing with R & D to improve and refine its "reconstituted product" range. Several talc producers are conducting feasibility studies on fine milling technologies.

8.3 Pricing & Sphere of influence

The variation in price between the different uses can be ascribed to the fact that different grades of talc and pyrophyllite are used for the different applications. Certain mines use internal transfers or have long-standing 'gentleman agreements' with specific consumers and manufactures. Local pyrophyllite prices are kept relatively low/ competitive through other refractory substitutes such as bauxite compounds and other cheap pyrophyllite imports.

Niche markets such as speciality paint and paper applications can command higher prices because of the superiority of local pyrophyllite-grade products and the lack of cheap substitutes. Energy costs are significant in terms of final product price, varying between 15-25% for uncalcined products and 35-45% for calcined products. On a consumer level, the price range for local, micronised talc varies from R1 600 to R4 800 per ton for pharmaceutical grades.

It is difficult to make a comparison between imported and local grade prices as talc is purchased for its physical and/ or chemical properties and these vary greatly between sources. Also, some international formulations require source-specific talc that may then be appropriately priced. The price consumers are prepared to pay is not determined by supply/ demand as such, but rather functionality and value-enhancement that such raw materials offer. Nano-pricing depends on the fineness, particle distribution and surface structure of the nano-particles.

The average pyrophyllite customer is about 300km from the mine. The maximum range for local products is 800km, although the international range has no limitations (this includes North America, Europe and Japan). The average talc customer is about 400km from the mine, with a maximum range of 1 500 - 1 700km.

8.4 Substitutes

Acceptable talc substitutes must adhere to the following prerequisites: low cost, high performance, high functionality and general availability of product. Talc substitutes include:

- ▶ Kaolin in paper,
- ▶ Special clays and mica in plastics,
- ▶ Kaolin and mica in both paint and rubber,
- ▶ Special clays and pyrophyllite in ceramics,
- ▶ Any cheaper, better-suited functional fillers, e.g. GCC, PCC and synthetic talc.

Pyrophyllite substitutes are application-specific – substitutes compete on functionality, overall performance and price. Substitutes include synthetic materials as well as synthetic crucibles for industrial diamond manufacturing; whilst other refractory substitutes include bauxite, mag-chrome bricks and any other alumina-based raw materials such as flint clays, dolomite, andalusite, and kyanite. Other white functional fillers include kaolin, talc, dolomite, PCC and GCC.

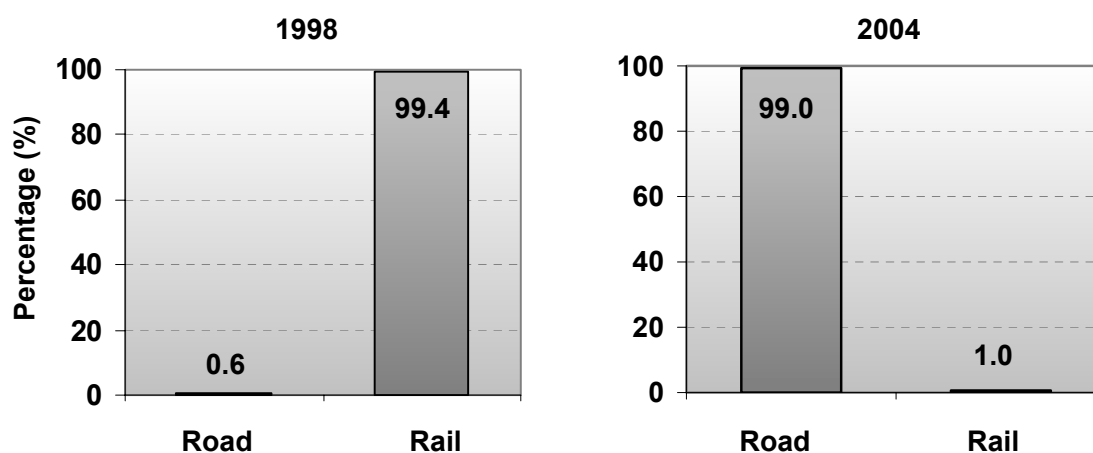
9. Logistics and Transport

Turnaround times have improved from 5 years ago, although this is not necessary with established customers where 1 or 2-month stockpiles are kept on-site at the consumer's premises. The rapid change from rail to road transport (Graph 11) and the need to address logistics problems efficiently, has led to the creation of marketing and logistics divisions by various companies to deal specifically with the placement of orders, order tracking, client problems and logistical/ transport arrangements – most companies have contracted out all transport.

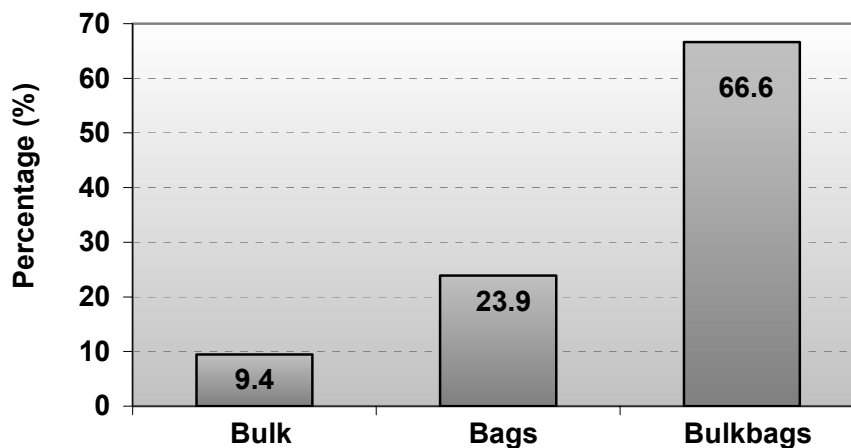
Road transport is the only mode of transport (99%), as opposed to 6 years ago where 0,6% of volumes sold were transported by road. Bulk transport is the dominant mode of transport by far (66,6%); bags (23,9%) and bulkbags (1 ton and 0,5 ton bags) representing about 9,4% of volumes sold (Graph 12). Bagged volumes are generally associated with high-value, low volume, product-specific niche markets.

Transport costs have become an important factor in price determination – up to 65% of the consumer price may be transport-related. Transport costs are negligible (<1% of final product price) for operators that manufacture high-quality, finished products. Location, quality and transport costs have barred some talc producers from specific markets.

Graph 11: Road / rail transport split for 1998 and 2004



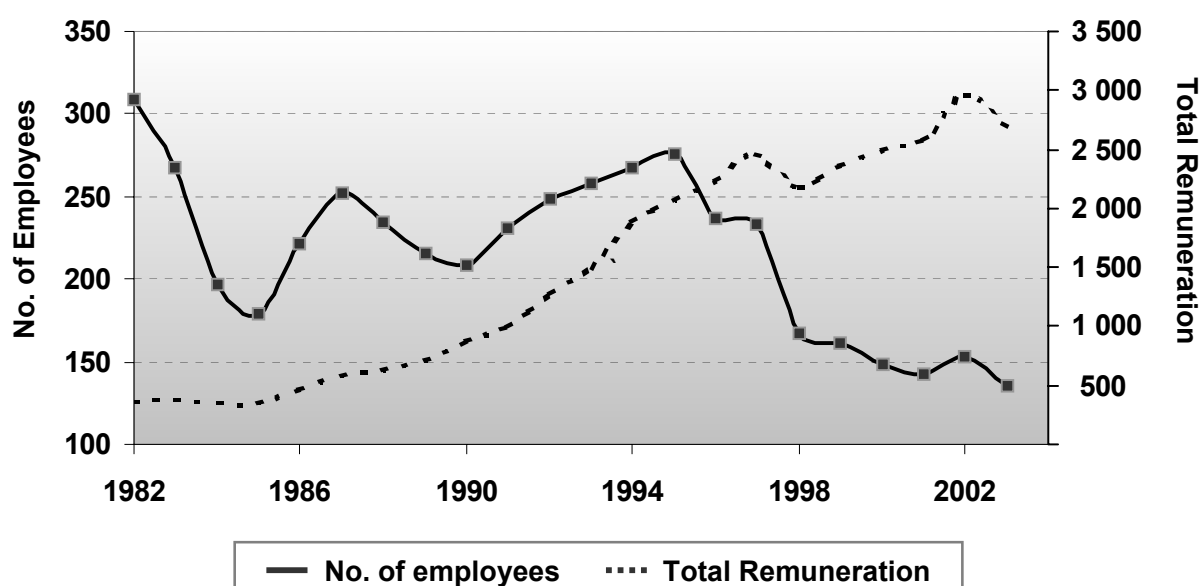
Graph 12: Packaging medium for talc and pyrophyllite products



10. Employment and Remuneration

There has been a steady decrease in employee numbers since 1996 (Graph 13). This has been attributed to mechanisation, cost cutting exercises and the downsizing of one pyrophyllite mine. Employee remuneration in the talc and pyrophyllite sector is in the lower echelons in the industrial sector – revenue generation is 0,7% of industrial mineral totals, whilst employee numbers and remuneration are about 1,2% and 0,6% respectively. There is a definite skills shortage in the talc mining districts.

Graph 13: Employment and remuneration, 1982 - 2003



11. Environmental, Safety & Community Initiatives

All employees must wear hard hats and masks in mining and processing areas. Most companies have regular/monthly health checks, annual thorough physicals and annual/ biannual chest X-rays. The use of dust hoods, dust collectors and other forms of dust suppression has minimized bentonite dust pollution significantly in production plants.

ISO 14001 and ISO 9001 compliancy, as well as NOSA accreditation, have assisted major role players in overall health and safety and proper environmental management. Employee compliance, with regard to mine health and safety is excellent, although external contactors seem less compliant.

All mining companies have been involved in community developments and social upliftment projects to some degree. This includes upgrading and building schools and workers' accommodation, supporting HIV projects, funding and providing Adult Basic Education Training, converting contract workers to full-time employees, providing extensive medical aid and pension plans. Several mining companies are offering careers in the talc and pyrophyllite industry, either through accelerated learning initiatives, offering bursaries to prospective learners, 'career-pathing' strategies, management courses, etc.

12. Threats, Problems and Risk in the Industry

Barriers for new entrants to talc and pyrophyllite markets are:

- ▶ High start-up costs,
- ▶ High production costs,
- ▶ Finding receptive markets,
- ▶ Good orebody characterisation,
- ▶ Good, favourably located deposit,
- ▶ Acute product- and industry knowledge,
- ▶ Technical know-how regarding processing,
- ▶ Continued capital expenditure from day one,
- ▶ Compliance costs regarding a new mine venture, and
- ▶ The specialised nature of these particular industries and associated markets.

Industry risk is low to moderate. Factors that have ensured stability in the industry include:

- ▶ Excellent, successful R & D initiatives,
- ▶ A lack of competitively-priced substitutes,
- ▶ Relatively stable supply and demand market forces,
- ▶ Producers' good reputation regarding service and quality,
- ▶ Pioneering technologies and material processing facilities, and
- ▶ Highly localised, substantial, quality pyrophyllite reserves and LOM plans.

New entrants would need a strong technological advantage in order to be able to take the market share from established producers. In such a situation it is generally easier to purchase an existing operation, or acquire an interest in one, than start a new operation. Using an established company's brand name to promote new products or materials, instead of promoting it oneself would be another alternative. E.g. Wonderstone Ltd's new wear chute lining products are sold through Ceramox, an established, ceramic manufacturer.

Other dense alumina manufactures, especially those using imported, cheap bauxite have won significant market share in armour plating and wear chute lining. Refractory applications requiring high-alumina content materials will always be a threat to pyrophyllite producers and manufacturers.

13. Conclusions / Summary

Favourable partnerships and the sharing of intellectual property is set to increase – an example of this is Wonderstone Ltd partnering with Saint-Gobain and Ceramox in recent years, as well as Idwala Minerals which has done much research with Scandinavian-based paper and pulp research teams. Chinese imports and -product substitution may increase in the near future – this could prove damaging to local and world pyrophyllite markets, particularly in high-end applications such as synthetic diamond manufacture and drill rig bits. However, the yield and consistency of Chinese pyrophyllite (which can only be used in low-end uses, such as grit or grinding media) does not compare to locally manufactured products.

In the refractory and wear-linings industry, substitutes such as olivine, bauxites, kaolin, flint clays and chromitic compounds are notable threats. Whitening agents, particularly alkaline-friendly products, also threaten pyrophyllite's use in paper manufacture. Although pyrophyllite has already established itself as an excellent pitch control agent in the paper industry, further growth may be expected with import replacement of other coating agents and high-end fillers.

In the talc industry, primary objectives would be to a) expand traditional markets, b) step-up value-addition and c) diversification and vertical integration. Value addition would include the use of cost-effective, cheap technologies to move away from low-value fillers (used in plastics, rubber and resins) to high-value applications such as functional fillers in cements and engineered plastics.

The pyrophyllite industry has implemented the above-mentioned strategies well. Continuous research and the development of niche markets such as ceramics (bullet-proof vests/ jackets), specific refractories, mineral fillers, cement, paper coating, civil applications, reconstituted products and high-yielding diamond manufacturing articles, basalt-substitution will bode the industry well. Possible research fields for talc would include ceramics, extender-filler applications, electrical insulators and hydraulic cements; as well as in-depth analysis of sintering characteristics; additive properties of alumino-silicates for improving impact strength of sintered bodies; the option of solid lubricants in composite bodies; fibreglass and hydraulic cements.

Although still in the R & D phase, current nano-talc research suggests that South Africa may well be producing a new generation of talc products in the next few years. Target markets for these surface-treated, ultra-fine talcs would include import replacement in cosmetic, pharmaceutical, paint and plastic applications. International changes with respect to environmental compliance (e.g. the substitution of tremolitic talc by pyrophyllite) may bring about interesting changes in the local alumino-silicate market in the medium and long-term.

There is a need to enhance awareness of talc and pyrophyllite's uses. Increased innovations and high-end niche markets will drive alumino-silicate demand considerably in the near future. A modest level of growth will take place, between 5-6% y-o-y (higher than that of the national economy); however higher forex rates may boost pyrophyllite exports significantly. Cheap, import substitutions remain a significant threat to all pyrophyllite producers. The medium price level and quality of local talc products (compared to other minerals, both local and imported) is a disadvantage in developing international markets. The exploration for high-grade talc deposits in South Africa must continue unabated. There is much scope for BEE partnerships and joint ventures within the Industry and its associated markets.

Addendums

Addendum 1:

General Montmorillonite Information

Chemical Formula: $(\text{Na,Ca})_{0.3}(\text{Al,Mg})_2\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot n(\text{H}_2\text{O})$

Composition: Molecular Weight = 549.07 gm

Alumina 18.46 % Al_2O_3

Silica 43.52 % SiO_2

Water 35.88 % H_2O

Soda 1.12 % Na_2O

Calcium 1.01 % CaO

Empirical Formula: $\text{Na}_{0.2}\text{Ca}_{0.1}\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2(\text{H}_2\text{O})_{10}$

Montmorillonite Crystallography

Axial Ratios: a:b:c = 0.5782:1:1.1129

Cell Dimensions: a = 5.17, b = 8.94, c = 9.95, Z = 1; beta = 99.9° V = 453.04

Crystal System: Monoclinic – Prismatic

Physical Properties of Montmorillonite

Cleavage: [001] Perfect

Colour: White, Grey white, Yellow, Brownish yellow, Greenish yellow

Density: 2 - 2.7, Average = 2.35

Diaphaniety: Translucent to Opaque

Fracture: Earthy - Dull, clay-like fractures with no visible crystalline affinities

Habit: Earthy - Dull, clay-like texture with no visible crystalline affinities

Hardness: 1.5 - 2 [Talc-Gypsum]

Luminescence: None

Lustre: Earthy (Dull)

Streak: White

Optical Properties of Montmorillonite

Optical Data: Biaxial (-), a = 1.485-1.535, b = 1.504-1.55, g = 1.505-1.55, bire = 0.0150-0.0200, 2V(Calc) = 0-24, 2V(Meas) = 5-30. Dispersion none.

Pleochroism (x): Colourless; Pleochroism (y): Colourless; Pleochroism (z): Colourless

Calculated Properties of Montmorillonite

Electron Density: $\rho_{\text{electron}} = 2.08 \text{ gm / cc}$
note: $\rho_{\text{Montmorillonite}} = 2.01 \text{ gm / cc}$
Photoelectric: $PE_{\text{Montmorillonite}} = 1.26 \text{ barns / electron}$
 $U = PE_{\text{Montmorillonite}} \times \rho_{\text{electron}} = 2.63 \text{ barns / cc}$
Radioactivity: $GR_{\text{api}} = 0$; Montmorillonite is not Radioactive

Montmorillonite Classification

Dana Class:

71.3.1a.2 (71) Phyllosilicate Sheets of Six-Membered Rings

(71.3) with 2:1 clays

(71.3.1a) Smectite group (Diocahedral Smectites)

71.3.1a.1 Beidellite $\text{Na}_{0.5} \text{Al}_2 (\text{Si}_{3.5} \text{Al}_{0.5}) \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

71.3.1a.2 Montmorillonite $(\text{Na}, \text{Ca})_{0.3} (\text{Al}, \text{Mg})_2 \text{Si}_4 \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

71.3.1a.3 Nontronite $\text{Na}_{0.3} \text{Fe}_2 (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

71.3.1a.4 Volkonskoite $\text{Ca}_{0.3} (\text{Cr}, \text{Mg}, \text{Fe})_2 (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

71.3.1a.5 Swinefordite $(\text{Li}, \text{Ca}_{0.5}, \text{Na})_{0.72} (\text{Li}, \text{Al}, \text{Mg})_{2.66} (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH}, \text{F})_2 \cdot 2(\text{H}_2\text{O})$

Strunz Class:

VIII/H.19-20 VIII - Silicates

VIII/H - Phyllosilicates (layered) Mica like with $[\text{Si}_4\text{O}_{10}]^{4-}$ and related groups

VIII/H.19 - Brammallite - Yakhontovite series

VIII/H.19-10 Brammallite $(\text{Na}, \text{H}_3\text{O})(\text{Al}, \text{Mg}, \text{Fe})_2 (\text{Si}, \text{Al})_4 \text{O}_{10} [(\text{OH})_2, (\text{H}_2\text{O})]$

VIII/H.19-15 Illite $(\text{K}, \text{H}_3\text{O})(\text{Al}, \text{Mg}, \text{Fe})_2 (\text{Si}, \text{Al})_4 \text{O}_{10} [(\text{OH})_2, (\text{H}_2\text{O})]$

VIII/H.19-20 Montmorillonite $(\text{Na}, \text{Ca})_{0.3} (\text{Al}, \text{Mg})_2 \text{Si}_4 \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

VIII/H.19-30 Beidellite $\text{Na}_{0.5} \text{Al}_2 (\text{Si}_{3.5} \text{Al}_{0.5}) \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

VIII/H.19-40 Nontronite $\text{Na}_{0.3} \text{Fe}_2 (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH})_2 \cdot n(\text{H}_2\text{O})$

VIII/H.19-50 Volkonskoite $\text{Ca}_{0.3} (\text{Cr}, \text{Mg}, \text{Fe})_2 (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

VIII/H.19-60 Swinefordite $(\text{Li}, \text{Ca}_{0.5}, \text{Na})_{0.72} (\text{Li}, \text{Al}, \text{Mg})_{2.66} (\text{Si}, \text{Al})_4 \text{O}_{10} (\text{OH}, \text{F})_2 \cdot 2(\text{H}_2\text{O})$

VIII/H.19-70 Yakhontovite $(\text{Ca}, \text{K})_{0.5} (\text{Cu}, \text{Fe}, \text{Mg})_2 \text{Si}_4 \text{O}_{10} (\text{OH})_2 \cdot 3(\text{H}_2\text{O})$

Source: www.webmineral.com / data / bentonite

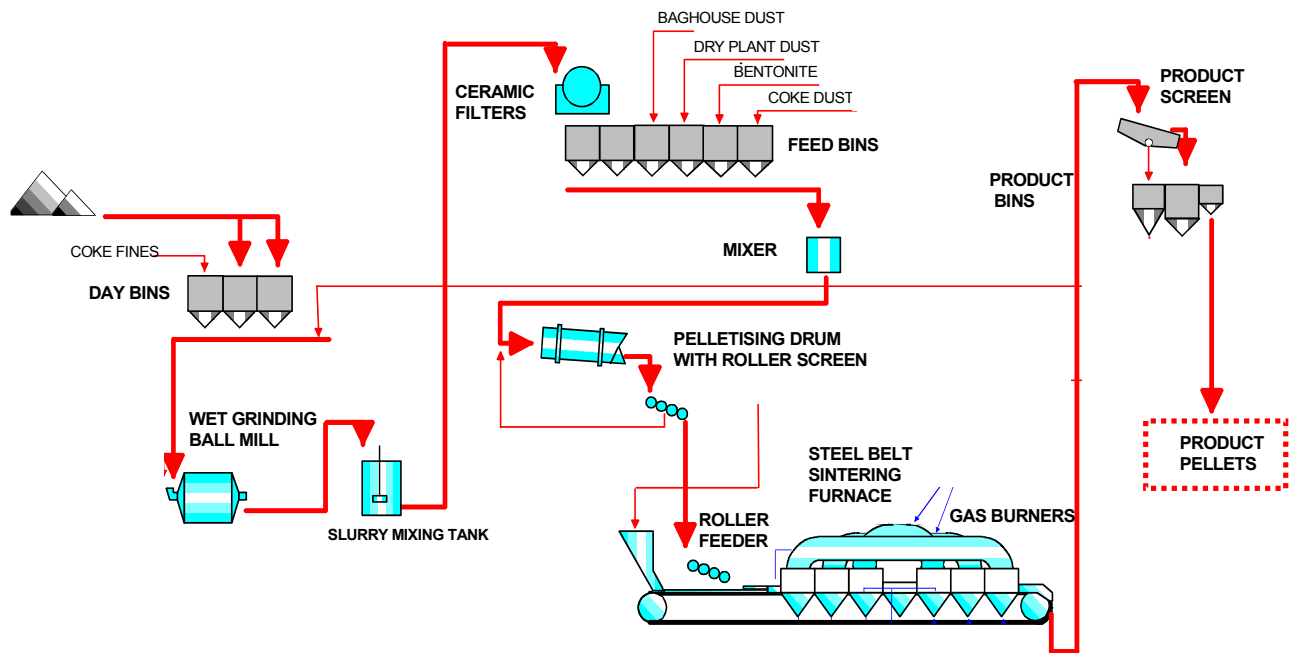
Abbreviations & nomenclature fully explained @ www.webmineral.com

Addendum 2:**End-user applications for bentonite**

Application/Use	Description
Oil industry	Drilling mud (Water-based muds, oil-based muds, synthetic-based muds).
Foundry casting	Bonding agent in foundry moulds for iron, steel & nonferrous casting applications.
Ore pelletising	Pelletising and briquetting of ferrous & non-ferrous fine ores (both main feedstock & discards).
Absorbents	Cat litter, industrial absorbents & desiccants, refining, filtering, clarifying & decolourising.
Agricultural	Pesticides, biocides, fertilizers, soil conditioners & animal feeds (pellitisation).
Civil engineering	Clay liners and barriers, sealants, liquid retention ponds, cathodic & seismic plugging.
Paper	Used in the pitch control, retention aid, de-inking and coating processes of paper.
Thickener	Bentonite is used in paints as a thickening, anti-sag and suspension agent.
Plasticiser	Additive in the mix of building bricks, ceramic bodies, cement, refractory mixes & bricks – it improves plasticity, reduces the moisture in the mix & lowers extrusion pressures.
Welding rods	Bentonite binds the fluxing materials in the rod coating together & acts as a suspending agent until the coating has dried.
Suspension agent	Used in mould coats in foundries to hold the various ingredients of the coat in suspension during application.
Other	Catalysis, ceramics, welding electrodes, high temperature greases, medical, pharmaceuticals, detergents, adhesive components, cosmetics, paint, paper, soaps, bathing minerals, dust control, polymers and resins.

Addendum 3:

Outokumpu process flow diagram



Courtesy of Outokumpu SA

Addendum 4:

World production and exports of bentonite, 2002

COUNTRY	PRODUCTION			COUNTRY	EXPORTS ⁺		
	kt	%	Rank ⁺		Kt	%	Rank ⁺
USA	4 110	32,9	1	USA	722	27,8	1
China	1 290	10,3	2	Italy	216	8,3	2
Greece	1 259	10,1	3	Netherlands	178	6,8	3
Italy	579	4,6	4	China	141	5,4	4
Turkey	559	4,5	5	Bulgaria	125	4,8	5
India	500	4,0	6	Turkey	107	4,1	6
Russia	500	4,0	7	India	92	3,5	7
Germany	495	4,0	8	Cyprus	81	3,1	8
Mexico	433	3,5	9	Greece	81	3,1	9
Japan	406	3,2	10	Indonesia	68	2,6	10
Brazil	319	2,6	11	UK	66	2,5	11
Spain	225	1,8	12	Australia	63	2,4	12
Bulgaria	212	1,7	13	Spain	63	2,4	13
South Africa ^l	103	0,8	19	South Africa ^l	11	0,3	26
Other	1 510	12,1	–	Other	573	18,3	–
TOTAL	12 500	100,0			2 600	100,0	

Notes: ⁺ For 2002 or latest available

^l Minerals Bureau

Totals may not add up due to rounding

Addendum 5:
S.A.'s production, local sales and exports of bentonite, 1982 - 2003

YEAR	PROD. Kt	LOCAL SALES			EXPORTS		
		Mass	Value (FOB)		Mass	Value (FOB)	
		Kt	R'000	R/t	kt	R'000	R/t
1982	30.8	13.4	1 216	91	1.0	42	42
1983	39.5	16.9	1 491	88	0.4	10	28
1984	41.8	16.2	1 694	104	0.9	64	70
1985	43.5	23.3	2 539	109	1.4	178	123
1986	48.3	25.6	3 654	143	1.6	228	142
1987	49.0	25.6	4 016	157	0.6	76	131
1988	66.8	41.0	7 314	179	0.8	59	73
1989	63.0	41.0	7 178	175	0.5	37	74
1990	66.1	39.3	8 985	228	0.9	87	99
1991	64.6	55.2	15 222	276	0	-	-
1992	44.0	36.2	11 189	309	0	-	-
1993	50.4	39.5	11 892	301	0.1	17	145
1994	71.8	51.5	14 912	289	0.4	65	153
1995	70.9	60.9	18 679	307	0.2	25	159
1996	48.1	50.3	15 315	305	0	-	-
1997	75.5	52.0	17 800	342	0	-	-
1998	48.4	55.5	17 231	311	0	-	-
1999	49.3	55.2	17 192	312	0,5	51,9	103
2000	90.1	62.5	21 378	342	0	-	-
2001	108.3	51.8	19 793	382	0	-	-
2002	101.1	67.8	32 916	485	10,0	4 065	408
2003	145,1	74,4	31 210	420	11,0	3 728	338

Note: Unit values calculated before rounding of mass and rand values

Addendum 6:**General Talc Information**

Chemical Formula: $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Composition: Molecular Weight = 379.27 gm

Magnesium 31.88 % MgO

Silicon 63.37 % SiO_2

Water 4.75 % H_2O

Empirical Formula: $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Synonym: Kerolite, Magnesium Talc, Soapstone, Steatite [massive]

Talc Crystallography

Axial Ratios: a:b:c = 0.5778:1:2.0668

Cell Dimensions: a = 5.27, b = 9.12, c = 18.85, Z = 4; beta = 100.016° V = 892.17

Crystal System: Monoclinic – Prismatic

Physical Properties of Talc

Cleavage: [001] Perfect

Colour: Pale green, White, Grey white, Yellowish white, Brownish white.

Density: 2.7 - 2.8, Average = 2.75

Diaphaniety: Translucent

Fracture: Uneven - Flat surfaces (not cleavage) fractured in an uneven pattern.

Habit: Foliated - Two dimensional platy forms

Scaly - Morphology like fish scales

Massive - Uniformly indistinguishable crystals forming large masses

Hardness: 1 - Talc

Luminescence: Fluorescent.

Luster: Vitreous - Pearly

Streak: white

Optical Properties of Talc

Optical Data: Biaxial (-), a = 1.538-1.55, b = 1.575-1.594, g = 1.575-1.6, bire = 0.0370-0.0500, 2V(Calc)=0-38, 2V(Meas)=0-30. Dispersion noticeable, r > v

Pleochroism (x): Colourless.

Pleochroism (y): Pale green

Pleochroism (z): Pale green

Calculated Properties of Talc

Electron Density: $\rho_{\text{electron}} = 2.76 \text{ gm / cc}$

note: $\rho_{\text{Talc}} = 2.75 \text{ gm / cc}$

Photoelectric: $PE_{\text{Talc}} = 1.57 \text{ barns / electron}$

$U = PE_{\text{Talc}} \times \rho_{\text{electron}} = 4.34 \text{ barns / cc}$

Radioactivity: $GR_{\text{api}} = 0$; Talc is not Radioactive

Talc Classification

Dana Class:

71.2.1.3 (71) Phyllosilicate Sheets of Six-Membered Rings

(71.2) with 2:1 Layers

(71.2.1) Pyrophyllite-talc group

71.2.1.1 Pyrophyllite $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.2 Ferripyrophyllite $\text{Fe}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.3 Talc $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.4 Willemseite $(\text{Ni},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.5 Minnesotaite $(\text{Fe},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Strunz Class:

VIII/H.09-40 VIII - Silicates

VIII/H - Phyllosilicates (layered) Mica like with $[\text{Si}_4\text{O}_{10}]_4^-$ - and related groups

VIII/H.09 - Talc series

VIII/H.09-10 Pyrophyllite $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-20 Ferripyrophyllite $\text{Fe}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-30 Macaulayite $(\text{Fe},\text{Al})_{24}\text{Si}_4\text{O}_{43}(\text{OH})_2$

VIII/H.09-40 Talc $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-50 Minnesotaite $(\text{Fe},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-60 Willemseite $(\text{Ni},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-65 Pimelite $\text{Ni}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

VIII/H.09-70 Kegelite $\text{Pb}_8\text{Al}_4\text{Si}_8\text{O}_{20}(\text{SO}_4)_2(\text{CO}_3)_4(\text{OH})_8$

Source: www.webmineral.com / data / talc

Abbreviations & nomenclature fully explained @ www.webmineral.com

Addendum 7:**General Pyrophyllite Information**

Chemical Formula: $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$
Composition: Molecular Weight = 360.31 gm
Alumina 28.30 % Al_2O_3
Silica 66.70 % SiO_2
Water 5.00 % H_2O

Empirical Formula: $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

Pyrophyllite Crystallography

Axial Ratios: $a:b:c = 0.5761:1:1.0439$
Cell Dimensions: $a = 5.161$, $b = 8.957$, $c = 9.351$, $Z = 2$; $\alpha = 91.03^\circ$, $\beta = 100.37^\circ$,
 $\gamma = 89.75^\circ$ $V = 425.14$ $\text{Den(Calc)} = 2.81$
Crystal System: Triclinic – Pinacoidal
X Ray Diffraction: By Intensity (I/I₀): 4.42 (1), 9.2 (0.9), 3.07 (0.85)

Physical Properties of Pyrophyllite

Cleavage: [001] Perfect
Colour: Brown green, Brownish yellow, Greenish, Grey green, Grey white
Density: 2.8 - 2.9, Average = 2.84
Diaphaniety: Translucent to opaque
Fracture: Flexible - Flexible fragments
Habit: Earthy - Dull, clay-like texture with no visible crystalline affinities
Hardness: 1.5 - 2 [Talc-Gypsum]
Luminescence: Fluorescent
Lustre: Pearly
Streak: White

Optical Properties of Pyrophyllite

Optical Data: Biaxial (-), $a = 1.534$ - 1.556 , $b = 1.586$ - 1.589 , $g = 1.596$ - 1.601 , bire = 0.0450-
0.0620, $2V(\text{Calc}) = 46$ - 60 , $2V(\text{Meas}) = 53$ - 62 . Dispersion none.
Pleochroism (x): Colourless
Pleochroism (y): Colourless
Pleochroism (z): Colourless

Calculated Properties of Pyrophyllite

Electron Density: $\rho_{\text{electron}} = 2.81$; gm / cc
note: $\rho_{\text{pyrophyllite}} = 2.81$ gm / cc
Photoelectric: $PE_{\text{Pyrophyllite}} = 1.65$ barns/electron
 $U = PE_{\text{Pyrophyllite}} \times \rho_{\text{electron}} = 4.62$ barns / cc
Radioactivity: GRapi = 0 ; Pyrophyllite is not Radioactive

Pyrophyllite Classification

Dana Class:

71.2.1.1 (71) Phyllosilicate Sheets of Six-Membered Rings

(71.2) with 2:1 Layers

(71.2.1) Pyrophyllite-talc group

71.2.1.1 Pyrophyllite $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.2 Ferripyrophyllite $\text{Fe}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.3 Talc $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.4 Willemseite $(\text{Ni},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

71.2.1.5 Minnesotaite $(\text{Fe},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Strunz Class:

VIII/H.09-10 VIII - Silicates

VIII/H - Phyllosilicates (layered) Mica-like layered silicates with $[\text{Si}_4\text{O}_{10}]_4$ - and related groups

VIII/H.09 - Talc series

VIII/H.09-10 Pyrophyllite $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-20 Ferripyrophyllite $\text{Fe}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-30 Macaulayite $(\text{Fe},\text{Al})_{24}\text{Si}_4\text{O}_{43}(\text{OH})_2$

VIII/H.09-40 Talc $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-50 Minnesotaite $(\text{Fe},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-60 Willemseite $(\text{Ni},\text{Mg})_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

VIII/H.09-65 Pimelite* $\text{Ni}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

VIII/H.09-70 Kegelite $\text{Pb}_8\text{Al}_4\text{Si}_8\text{O}_{20}(\text{SO}_4)_2(\text{CO}_3)_4(\text{OH})_8$

Source: www.webmineral.com / data / pyrophyllite

Abbreviations & nomenclature fully explained @ www.webmineral.com

Addendum 8:**End-user applications for pyrophyllite & talc**

Application/Use	Description
Oil industry	Drill rig bits
Abrasives	Grit and abrasive applications.
Refractories	Materials that provide temperature and chemical resistance, thermal shock absorption, electrical insulation and corrosion protection. Pyrophyllite is used in monolithic refractories, gunning, ramming, plastic refractory compositions, castable mixes, firebricks, kiln car refractories, metal pouring refractories, foundry mould coatings, wear linings, anti-corrosive linings and cupola liners.
Plasticiser	Talc is used in appliance panels, whiteware, plastic furniture, automotive parts, interior and exterior trim. It is an anti-blocking agent in low-density polyethylene and acts as a nucleating agent in semi-crystalline polymers.
Paint	Talc is used in viscosity control in water- and solvent-based formulations. It can be used in heavy-duty applications such as marine coatings and steel structure coatings.
Rubber	Used as reinforcing filler in carpet backing, valve rubber and cable insulation, and as a mould release agents for wires, cables and tyre manufacture.
Ceramics	Pyrophyllite and talc are used in wall tile, sanitaryware and vitreous china manufacture. Can be used in speciality ceramics (electrical porcelain) and prevents crazing and cracking in glazes.
Pharmaceutical & Cosmetics	Talc can be used in talcum powder, antiperspirant, sticks, soaps, cleansing bars, creams and lotions. It can be used in dusting or in tablets as a lubricant or diluent.
Absorptive / Lubricating	Talc is used in roofing products, in foods as an anti-stick coating agent (chewing gums, candies and cured meats) and as a processing aid in olive oil production. Talc and pyrophyllite can be used as anti-caking agents, dispersing agents, dye lubricants, dry carriers (pesticides, herbicides, fungicides, insecticides and fertilizers) and animal feed suspension agent.
Other fillers	Texture paints, wallboards and -cement and mastics, plastics, paper, rubber, vinyl tiles.
Other	High temperature burner and atomizing nozzles, laboratory ware, welding rods, prototyping, vacuum-, induction- and electrical heating, plasma cutting, water treatment, road construction (calcined pyrophyllite), anti-skid agents, high-temperature and white cements, crucibles for synthetic diamond manufacture, mechanical seal faces, sleeve bearings, electric and thermal insulators.

Addendum 9:

S.A.'s production, local sales and exports of talc and pyrophyllite, 1982 - 2003

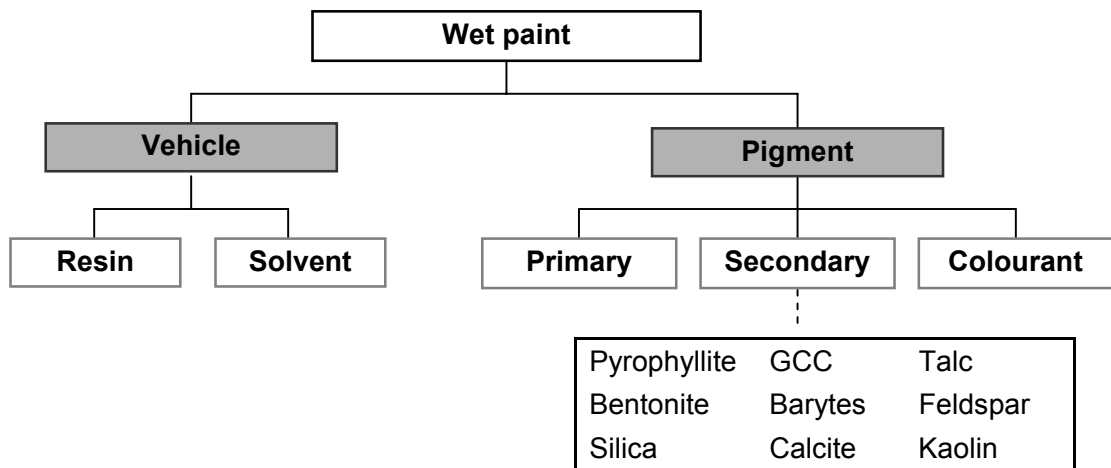
YEAR	PROD.	LOCAL SALES			EXPORT SALES		
		Mass	Value (FOB)		Mass	Value (FOB)	
		kt	R1 000	R/t	kt	R1 000	R/t
1982	13.81	9.19	0 731	80	0.96	0 506	525
1983	11.19	8.82	0 934	106	0.53	0 371	706
1984	14.41	11.31	1 061	94	0.12	0 067	544
1985	14.45	9.76	1 142	117	0	-	-
1986	13.25	9.02	1 206	134	0	-	-
1987	10.52	10.68	1 757	165	0	-	-
1988	11.64	13.70	2 753	201	0.50	0 886	1 782
1989	13.73	12.16	2 641	217	1.41	2 351	1 669
1990	12.48	9.75	3 169	325	1.38	2 629	1 912
1991	11.78	9.28	3 493	376	2.18	4 418	2 030
1992	13.32	12.41	5 330	429	2.78	6 630	2 384
1993	13.09	14.65	6 749	461	4.24	11 307	2 669
1994	22.32	14.20	6 113	430	4.54	14 435	3 179
1995	21.36	21.44	13 134	613	4.03	14 768	3 665
1996	18.54	20.98	10 638	507	1.90	9 470	4 989
1997	23.18	21.60	12 158	563	1.86	11 551	6 224
1998	22.83	18.14	11 736	647	1.46	11 737	8 066
1999	21.15	19.14	15 045	786	1.76	16 521	9 376
2000	17.59	20.49	18 930	924	2.49	25 433	10 198
2001	17.08	22.70	22 179	977	1.40	18 617	13 298
2002	18.28	23.63	26 921	1 139	0.92	14 584	15 852
2003	21.14	24.93	26 698	1 071	0.24	8 506	35 590

Note: Unit values calculated before rounding of mass and rand values

Addendum 10:

Composition of paint

Paint can be described as a pigmented liquid that protects and beautifies substrates. Various raw materials are utilized to make this pigmented liquid. Each of these products can fall into one of the following categories: pigment, resin, solvent. These three basic categories make up two portions of paint: First, the vehicle which is the liquid portion of the paint (resin and solvent), and second, the pigment which is the solid portion of the paint.



- ▶ The **resin** is the film-forming portion of the paint. Resin and pigment constitute the solids in the dry paint film.
- ▶ The **solvent** is used to thin or disperse the resin. This dispersion enables easier application and formation of the paint film.
- ▶ **Primary pigment** is commonly composed of titanium dioxide. The amount of primary pigment impacts greatly on the hiding capabilities of the paint film and UV protection.
- ▶ **Secondary pigments** are pigments such as talc, silicas, calcium carbonate, mica, which have little impact on hiding. They are used as fillers to help control viscosity, leveling, sheen, etc.
- ▶ **Colourants** are the tinting liquids dispensed by a tinting machine to bring the paint to the final colour desired.

The basic function of the **vehicle** is to:

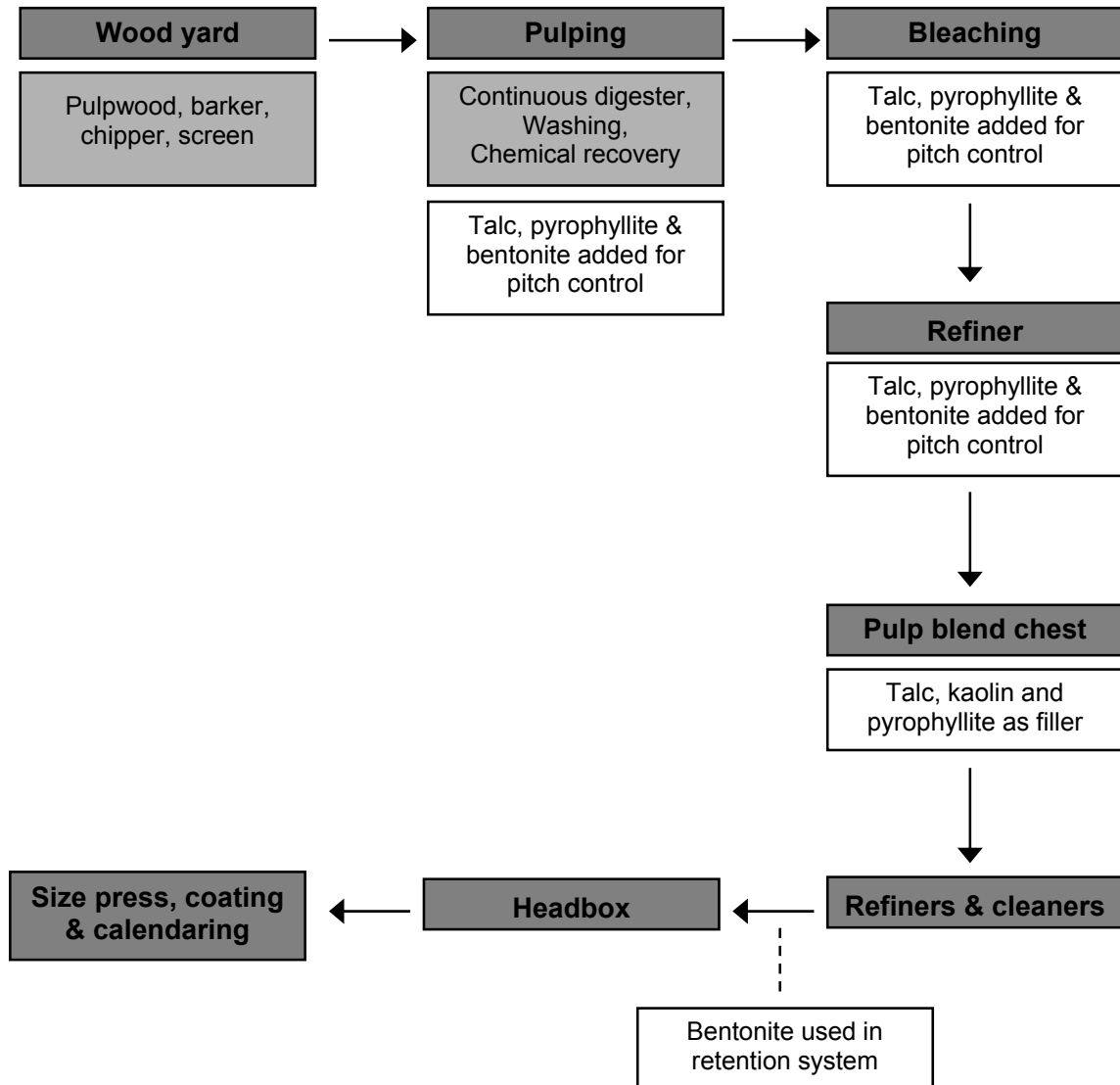
- Hold pigment together,
- Provide adhesion of the paint film to the substrate,
- Provide much of the protection the paint film offers,
- Help provide the film-forming portion of the paint film.

The basic function of the **pigment** is to:

- Improve weather resistance,
- Decrease moisture permeability,
- Help control corrosion and mildew,
- Help control the gloss of the paint film,
- Provide hiding, stain resistance and colour,
- Provide strength and toughness to the binder, and
- Help provide adhesion of the paint film to the substrate.

Addendum 11:

Pulp-to-paper manufacturing flow diagram



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Queries, updates & corrections:

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