REPORT R87/2010

CERAMIC INDUSTRY IN SOUTH AFRICA, 2010

DIRECTORATE: MINERAL ECONOMICS

mineral resources
Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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Picture courtesy of:
Limpopo ceramics
Ceramic industries

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This, the 1st edition, published in December 2010

ISBN:
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1. INTRODUCTION

The word “ceramics” comes from the Greek word “keramikos” meaning pottery. Most traditional (conventional) ceramic products are made from clay or clay mixed with other material. This clay is shaped and exposed to heat to make products such as tableware and decorative ceramics. In modern terms, ceramics is the art and science of making objects from inorganic, non-metallic materials and subjecting these materials to heat.

A variety of raw materials are required for the production of ceramic products. Some raw materials can be used satisfactorily on their own, without any addition of other materials. However, different kinds of materials are blended to give the desired properties. This is particularly so, for the manufacture of high quality ceramics, such as porcelain, where plastic and non-plastic clays together with fluxes such as feldspar and silica are accurately proportioned to develop specific properties for finished ceramic articles. In addition, purity and consistency are extremely important determinants in manufacturing high quality ceramics.

South Africa is well endowed with suitable material for the production of a wide range of ceramic products. High quality primary kaolin, ball clays (commonly known as plastic clays), feldspar and silica occur abundantly throughout the country. These resources can provide a wide range of opportunities for small scale miners, as they are easy to extract and beneficiate into ceramic products. For the purpose of this report only raw material associated with “conventional ceramics” will be discussed.

2. RAW MATERIALS

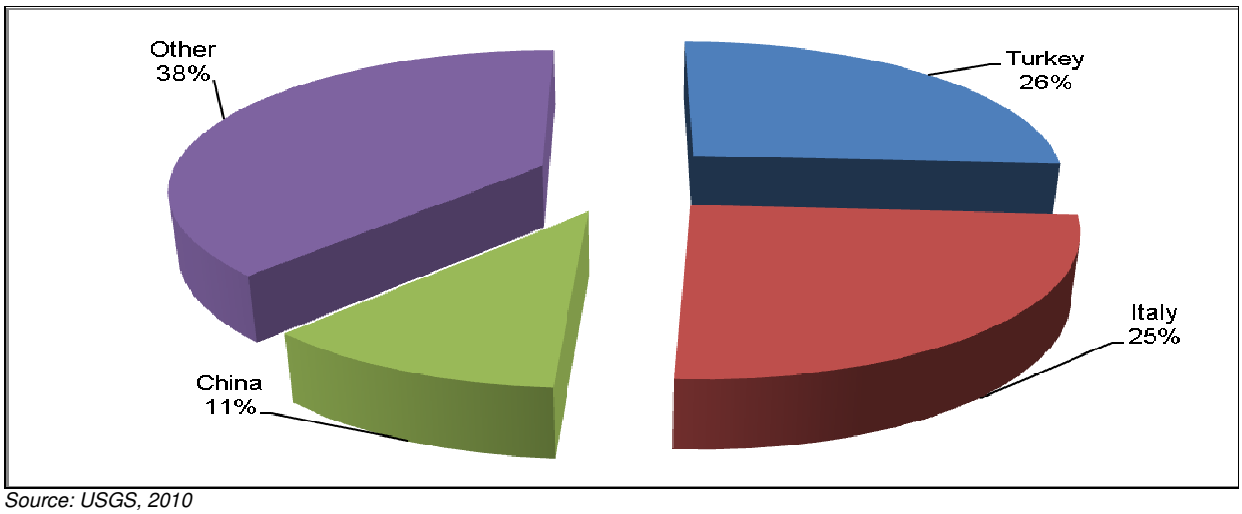
A wide range of materials including both natural and synthetic materials are employed by the ceramic industry to match the diversity of its product range. Most of the commodities which are considered to be in abundant supply are used in conventional ceramics manufacturing, with a fair amount also being used in small quantities in more advanced applications.

2.1. Feldspar

Feldspar is the mineral name given to a group of minerals distinguished by the presence of aluminium (Al) and silica (SiO_4). This group includes aluminium silicates of sodium oxide, potassium oxide or calcium oxide. Feldspar is the most abundant mineral group on earth. The minerals included in this group are orthoclase, microcline and plagioclase feldspar. They form in a variety of thermal environments, during the crystallization of magma, by metamorphism of rocks and in sedimentary processes. Feldspar is mined from large granite bodies, pegmatites and from sands composed mostly of feldspar.

World production of feldspar amounted to 18.9 Mt in 2009. Turkey was the largest producer at 26 percent, followed by Italy's 25 percent and China's 11 percent at second and third place respectively (Fig. 1). South Africa plays a minor role, accounting for 0.5 percent of the total world output.

FIGURE 1: WORLD PRODUCTION OF FELDSPAR, 2009



Source: USGS, 2010

In South Africa, Feldspars are found in pegmatite and granite bodies, feldspar-bearing pegmatites occur in the Mica and Gravelotte areas in the Limpopo and Northern Cape Provinces. In Limpopo Province, the pegmatites are generally associated with the Goudplaats Gneiss of Swazian age.

The pegmatites of the Northern Cape are confined to a belt between 15 and 30 km wide and approximately 550 km long. They are associated with various tectonic intrusive rock units (all of Mokolian age), notably the Vioolsdrif, Hoogoor and Keimoes Suites and metamorphic rocks in their immediate vicinity. Most of the pegmatites show a degree of zoning; the cores usually consist of quartz and microcline-perthite, and therefore, a considerable number of the larger zoned bodies are suitable for production of potassium feldspar.

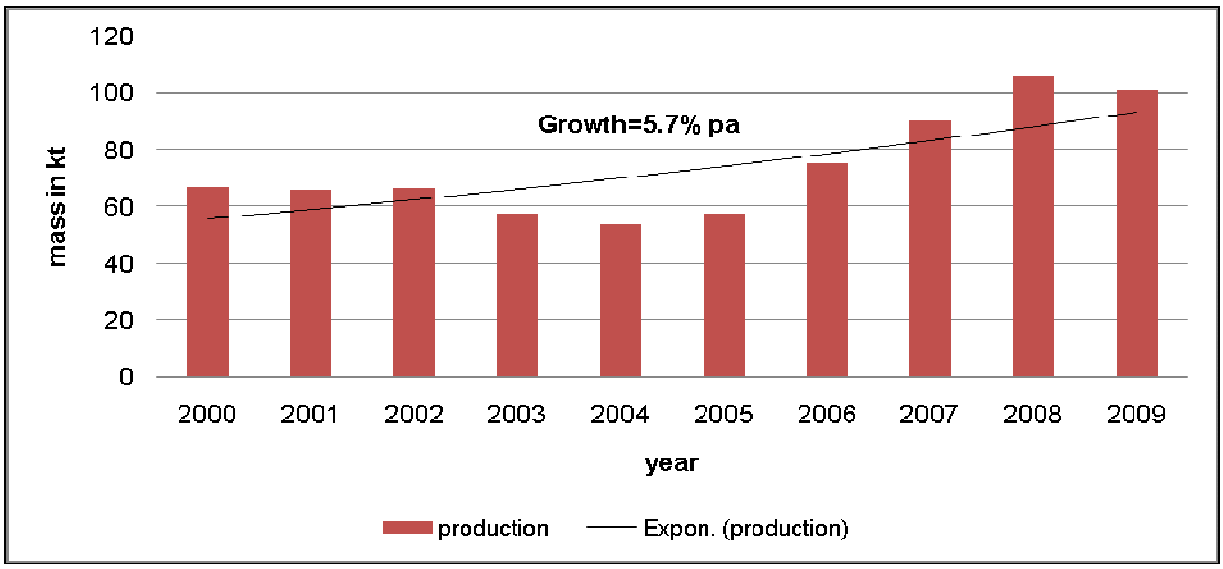
Although the pegmatite bodies in South Africa are generally dyke-like at surface, their vertical morphology is notoriously unpredictable. As a consequence, it is generally very difficult to accurately determine reserves of pegmatite minerals. However, regional surveys carried out on the various pegmatite fields since 1960 have shown that there are sufficient reserves of feldspar to meet the country's medium to long term requirements.

The permitted impurities in ceramic feldspar (both K-feldspar and Na Feldspar) should not be more than 0.1% Fe_2O_3 for high grade ceramics, and not more than 0.3% Fe_2O_3 for standard grade.

Feldspar is used as a suitable source of alumina and alkali, with main markets being in the manufacture of ceramics and glass. Its applications are in ceramic white wares, ceramic glazes, and dinnerware. Feldspar can be substituted by other minerals of similar properties such as pyrophyllite, clays, talc and quartz. However, its abundance makes these substitutes unnecessary for the foreseeable future.

In South Africa, production of feldspar has been increasing at an average annual rate of 5.7 percent for the past ten years, due to strong demand from the ceramic and glass industries (Fig. 2). These industries account for approximately 85 to 90 percent of feldspar consumption.

FIGURE 2: SOUTH AFRICA'S PRODUCTION OF FELDSPAR, 2000–2009



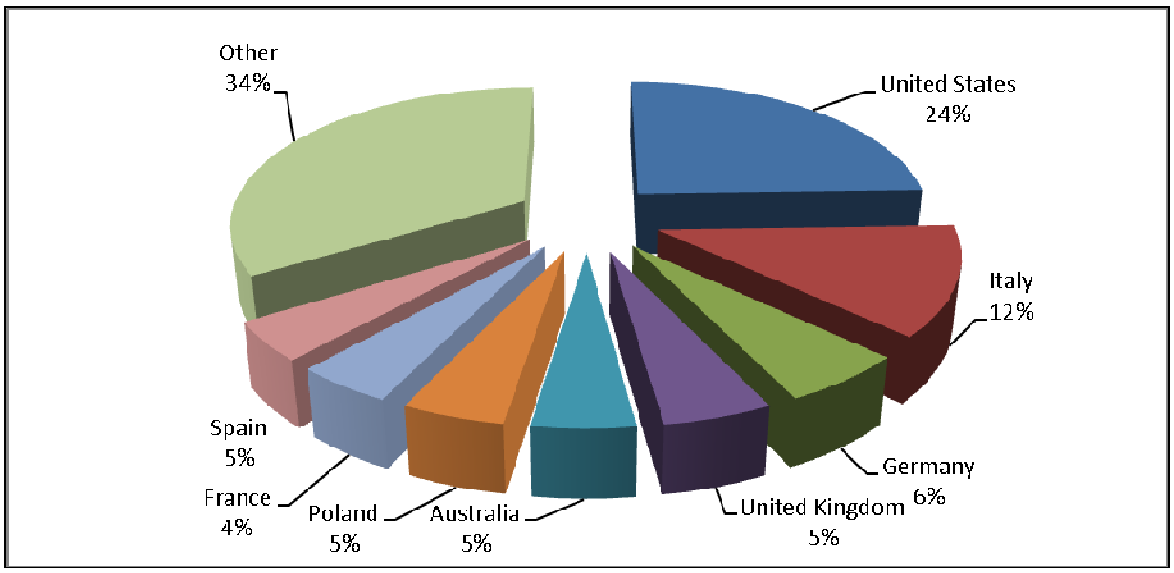
Source: DMR, Directorate Mineral Economics

2.2. Silica

The chemical compound silicon dioxide, also known as silica is an oxide of silicon with a chemical formula of SiO_2 . Silica is most commonly found in nature as quartz, it exists in five forms, viz., sand, quartzite, massive quartz, quartz crystals and silcrete. Silica is the second most abundant mineral in the Earth's crust after feldspar. It is the starting material for the production of silicate glasses and ceramics.

Production of silica decreased by 7.4 percent to 112 Mt in 2009, compared with 121 Mt in 2008, due to lack of demand from major consuming markets. The United States remained the largest producer and consumer of silica accounting for 24.5 percent of the overall world production, followed by Italy and Germany at 12.5 and 5.8 percent respectively (Fig. 3). South Africa contributed 2.6 percent to the global production.

FIGURE 3: WORLD PRODUCTION OF SILICA, 2009



Source: USGS, 2010

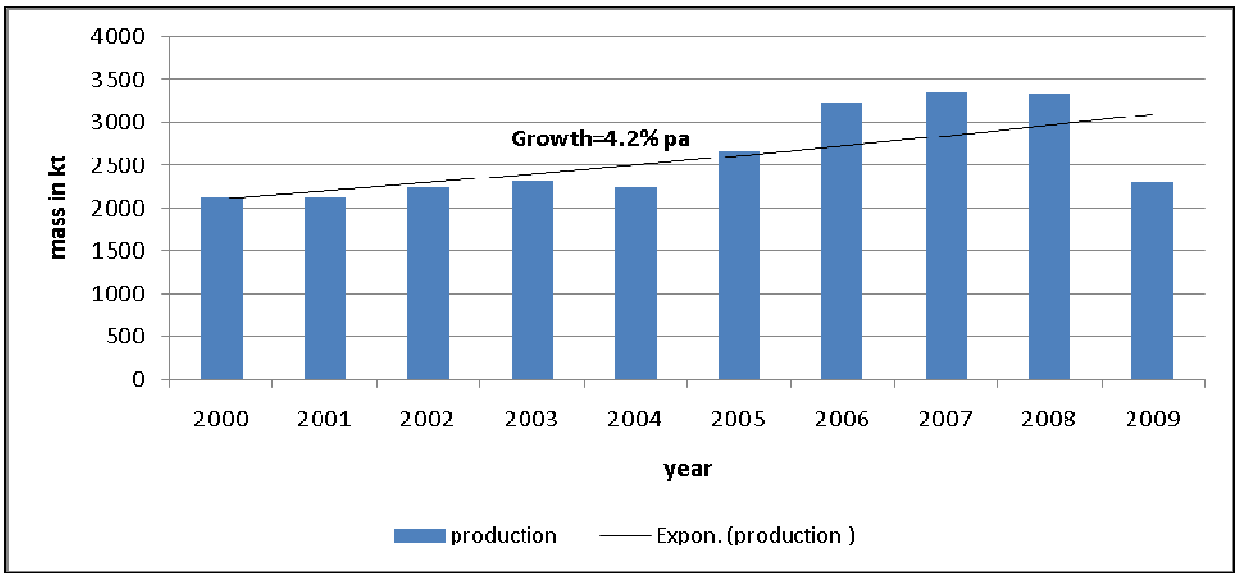
Major silica deposits occur in Gauteng, Limpopo, Mpumalanga and Eastern Cape Provinces in South Africa. In Mpumalanga Province, a high grade quartzite occurs on Moabsvelden, about 10km east of Delmas, as well as in the Belfast areas, where the deposits consist of exceptionally pure quartz (arenites) and could yield high grade SiO_2.

In Limpopo Province, the ore body at Witkop Silica Mine, 4km south east of Polokwane consist of approximately 4 quartz pods separated in places by zones of granite gneiss (Turfloop Granite) having a 55% grade of quartz. In the Phalaborwa area the ore body occurs in massive form and is exploited for mica, vermiculite, feldspar and silica.

Silica is primarily used in the production of glass, ceramics and chemicals. Lump silica is used mainly as a flux in the manufacture of silicon and ferrosilicon, with applications found in the chemical, metallurgical and electronic industries.

South Africa's production of silica has been increasing at an average annual rate of 4.2 percent between 2000 and 2009 (Fig. 4), as a result of high demand from the construction industry in the build up to the 2010 soccer world cup. However, the decline in 2009 was as a result of the decline in demand from other major consuming markets.

FIGURE 4: SOUTH AFRICA'S PRODUCTION OF SILICA, 2000-2009



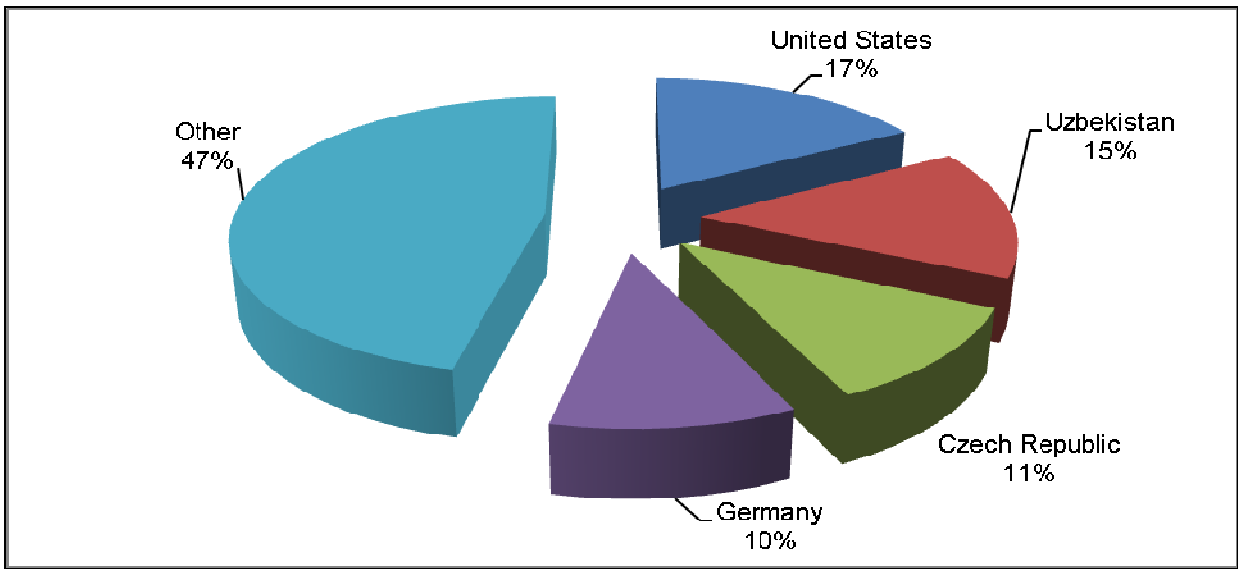
Source: DMR, Directorate Mineral Economics

2.3. Kaolin

Kaolin is the name used for naturally occurring, white, fine-grained, non-plastic, earthy material, essentially composed of kaolinite, which is a hydrated oxide of silica and alumina. Kaolin deposits are classified as either primary or secondary. Primary kaolins result from residual weathering or hydrothermal alteration of alkali feldspar-rich rocks such as granites or gneiss, whilst secondary kaolins are of sedimentary origin. South Africa has both primary and secondary deposits.

World production of kaolin decreased by 14.8 percent to 30.6 Mt in 2009, compared with 35.9 Mt in 2008. This was a result of lower demand from the world paper markets. The largest producer is the United States accounting for 17 percent of the total world production, followed by Uzbekistan at 15 percent and Czech Republic and Germany at 11 and 10.6 percent respectively (Fig. 5).

FIGURE 5: WORLD PRODUCTION OF KAOLIN, 2009



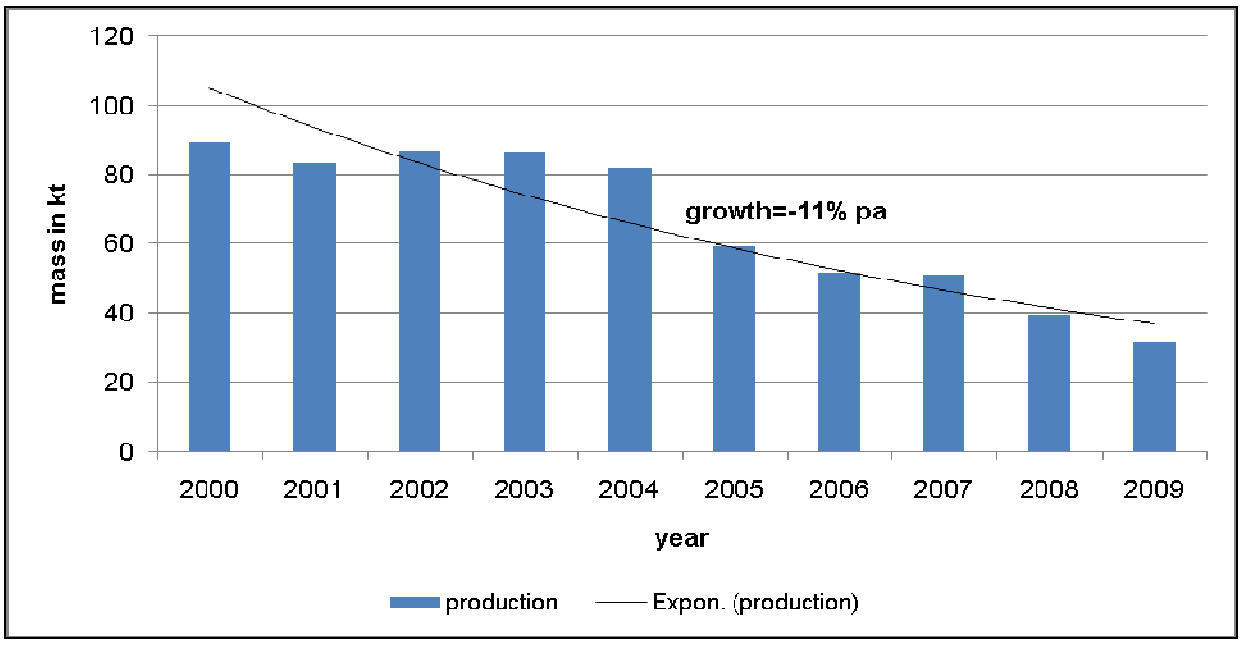
Source: USGS, 2010

South Africa's reserves of kaolin, which are estimated to be 110 Mt, have a 46 to 73 percent Silica (SiO_2) content and 19 to 38 percent alumina (Al_2O_3). Economic deposits occur in the Cape Peninsula (Western Cape), Grahamstown area (Eastern Cape), and Pretoria / Bronkhorstspruit area (Gauteng).

In 2009, South Africa's production of kaolin amounted to 30.1 kt (Fig. 6). South Africa's production of kaolin has been decreasing at 11 percent per annum for the last ten years, due to decreasing demand from the paper industry and cheap ceramic imports from China, Korea and Vietnam.

The largest consumer of kaolin is the paper and ceramics industries, which account for more than 60 percent. Kaolin is mainly used for quality white-ware, such as porcelain and earth-ware crockery. Colour is a very important requirement, but other properties such as particle size and dry strength are usually specified. Ceramic kaolin covers quite a wide range, but many of the grades are prepared for traditional use only.

FIGURE 6: SOUTH AFRICAN PRODUCTION OF KAOLIN, 2000-2009



Source: DMR, Directorate Mineral Economics

2.4. Ball clay (plastic clay)

Ball clays apply to clays consisting mainly of kaolinite having fine particle size containing organic material, which imparts good plastic properties. Ball clays are extensively used in the whiteware ceramic industry as an ingredient in clay bodies composed largely as non-plastic materials such as kaolin, feldspar and silica.

The most suitable ball clays for the ceramics industry occur in 4 regions of the world: Devon and Dorset in UK, Kentucky, Tennessee and Texas in the USA, northern Thailand and central Europe. In certain clays, illite is the predominant mineral. In such cases the term 'plastic clays' is used. However, industrially speaking, ball clays and plastic clays are synonymous. The UK is the leading producer and exporter of high quality ball clay.

In South Africa, ball clays are found in the Western Cape (Stellenbosch area) and Mpumalanga Province (Carolina District). Plastic clay has been exploited in the Western Cape for several decades mainly for use in the whiteware ceramic industry.

Ball clays are used in many different industries, but they are a vital component in ceramic manufacturing. Kaolin produces a very white colour when it is fired, but when used alone it is

brittle and weak and must be mixed with ball clay to produce a workable, malleable raw material. These clays are valued by the ceramics industry for their white-firing properties, which are determined by the levels of iron and other coloring/fluxing oxides within the clay. The ceramics industry, which is dominated by the tile and sanitaryware markets, is the biggest consumer of ball clays.

2.5. Talc

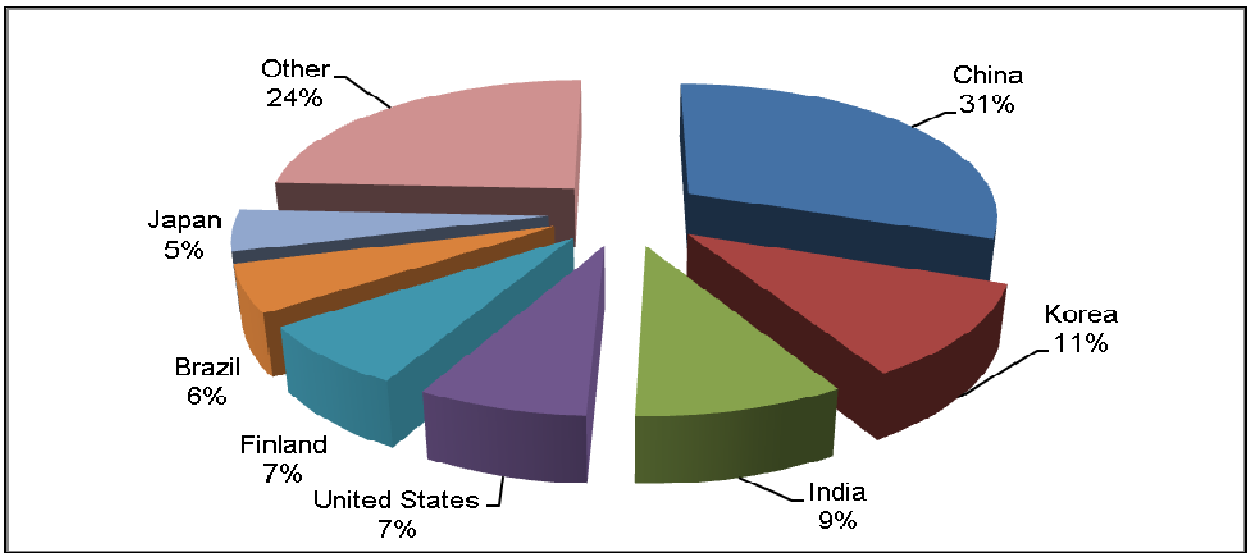
Talc is a hydrated magnesium silicate, which has been derived from the Arabic word "*talq*", meaning mica. Like mica, talc can be found in sheet-like masses, be foliated or have a scaly appearance, and has perfect basal cleavage that allows it to split into wavy, flexible, non-elastic flakes.

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.

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 are 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, particularity in the Ottosdal area (North West Province).

World production of talc decreased by 4 percent to 7 212 kt in 2009, compared with 7 510 kt in 2008, due to the lack of demand from major markets. China is the leading producer of talc, accounting for 31 percent of world production. It is followed by Korea and India accounting for 11 and 9 percent respectively (Fig. 7).

FIGURE 7: WORLD PRODUCTION OF TALC, 2009



Source: USGS, 2010

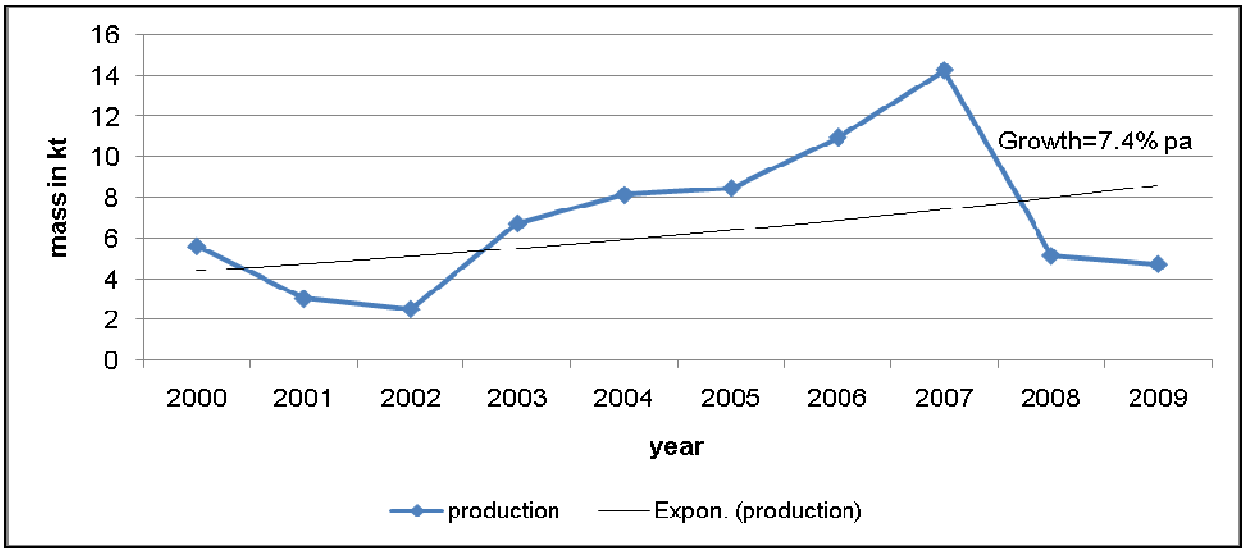
Economically viable deposits of talc are found in Mpumalanga province, in Barberton and Nelspruit regions. Barberton greenstone belt rocks host a number of talc deposits, several have been exploited. The talc generally contains a lot of impurities and is of an industrial grade, although isolated pods of high quality talc do occur. Other deposits are found in messina district (Limpopo province), in Nqutu district and Tugela Valley between Kranskop and Eshowe (Kwazulu-Natal Province, rocks of the Chuniespoort Group of the Transvaal Supergroup in Gauteng as well as in the Northern Cape Province(Gordonia, Prieska, Kuruman, Barkly West and Kimberly Districts).

Paper (20%), ceramics (28%), plastics (10%), and paints (21%) account for about 80% of world talc demand. The talc market depends on the construction (paint, ceramics and plastics) and the paper industries. However, the automotive sector (for talc use in autoplastics), housing sector (for talc in ceramics/roofing/paint) and advertising (talc consumption in the paper market) are currently the key drivers for talc.

Industrial talc (which is often marketed as talc) is a major component in the manufacture of ceramics, various porcelain, floor and wall tiles, electrical insulators and refractories. Ceramics consume more than 30 percent of talc output. The markets for various types of ceramics require a large construction industry, where ceramics are standard.

The production of talc has been increasing at an annual average rate of 7.4 percent since 2000. However, production decreased by 64 percent to 5.1 kt in 2008 with a further dip to 4.7 kt in 2009, as a result of the decline in demand from the residential building market. As a result of the decrease in demand from construction-related applications, such as adhesives, ceramic tiles, joint compounds, paint, roofing, rubber and sealants (Fig. 8).

FIGURE 8: SOUTH AFRICA'S PRODUCTION OF TALC, 2000-2009



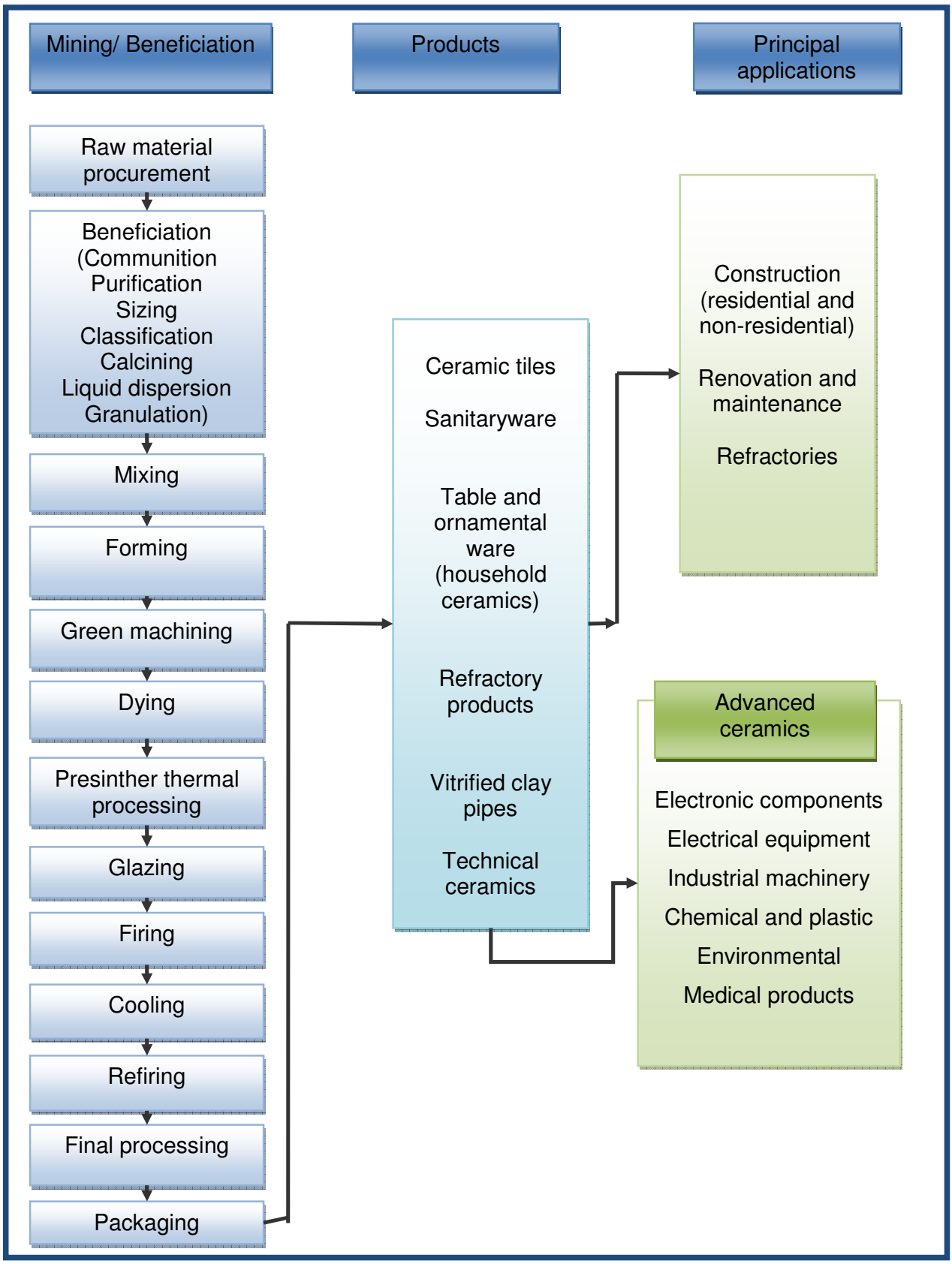
Source: DMR, Mineral Economics

3. MANUFACTURING OF CERAMICS

Ceramics are typically produced by applying heat onto processed clays and other natural raw materials (such as kaolin, feldspar and silica) to form a rigid product. Ceramic products that use naturally occurring rocks and minerals as a starting material must undergo special processing in order to control purity, particle size, particle size distribution, and heterogeneity. These attributes play a big role in the final properties of the finished product. Some ceramic products use chemically prepared powders as their starting material. These synthetic materials can be controlled to produce powders with precise chemical compositions and particle size.

The next step is to form the ceramic particles into a desired shape. This is accomplished by the addition of water and/or additives such as binders, followed by a shape forming process. Some of the most familiar forming methods for ceramics include extrusion, slip casting, pressing, tape casting and injection moulding. After the particles are formed, these "green" ceramics undergo a heat-treatment (called firing or sintering) to produce a rigid, finished product. Some ceramic products such as electrical insulators and tiles may then undergo a glazing process. The glaze consists of zircon, feldspar, calcite, kaolin and zinc oxide. Ceramics for advanced applications may undergo a machining and/or polishing step in order to meet specific engineering design criteria (Fig. 9).

FIGURE 9: CERAMICS INDUSTRY FLOW CHART



Source: DMR, Mineral Economics

4. WORLD SUPPLY AND DEMAND

World production of sanitary and tile products amounted to 311 million pieces and 8.495 million m^2 respectively in 2008, while that of tableware products amounted to 1.43 Mt. China was the world leader in the production of ceramic products, accounting for 28 percent of sanitary output, 38 percent of all tiles produced and 49 percent of tableware market.

In 2008, China was the leading exporter of ceramic products accounting for 24 percent, followed by Italy's 14 percent and Germany's 11 percent. The biggest importers were the USA accounting for 12 percent of world imports followed by Germany's 8 percent and France's 7 percent.

5. SOUTH AFRICA'S CERAMIC MARKETS

While there is demand for basic building material in South Africa, the ceramics industry is a prime example of downstream utilisation of resources through the local manufacturing of a wide range of household and industrial products.

Ceramic Industries Ltd is the largest producer of floor and wall tiles accounting for 50 percent of local sales, as well as a major sanitaryware manufacturer in South Africa.It has 4 tile factories, 1 sanitaryware factory and 1 acrylic bath factory in South Africa. According to Ceramic Industries , South African tile and sanitary markets shrunk by an estimated 20 and 30 percent respectively, as a result of lower sales volume in urban areas and in the contractor markets.

Ceramic Industries consists of four tile factories, 1 sanitary factory and 1 acrylic bath factory:

- Betta Sanitaryware (Krugersdorp, west of Johannesburg), produces glazed porcelain sanitaryware
- Vitro (west of Vereeniging, Vaal triangle), produces full bodied glazed and unglazed, extruded punched tiles for indoor and outdoor use
- Pegasus (adjacent to vitro), matt and shinny glazed, pressed floor tiles
- Samca floor tiles (Hammanskraal Babelegi, Tshwane North), the pressed glazed tile for indoor use

- Samca wall tiles (adjacent to samcar floor tiles), the manufacturer of pressed, glazed wall tiles for the commodity and fashion markets
- Aquarius (next to Betta), acrylic baths and shower trays

Vaal Sanitaryware, a subsidiary of the Group Five Construction and Materials Manufacturing Company is South Africa's leading manufacturer and supplier of fireclay and vitreous china sanitaryware products. Vaal Sanitaryware and Betta Sanitaryware supply approximately 80 percent of the local sanitaryware market.

- Vaal Sanitaryware (Meyerton), produces vitreous china sanitaryware

Johnson Tiles is a division of Norcros SA (Pty) Ltd which is a wholly owned subsidiary of Norcros UK**.** Johnson Tiles is one of the world's finest producers of ceramic tiles. Johnson Tiles manufactures a wide range of floor tiles in its South African factory, and is able to import many ranges from the Johnson Ceramics International associate companies around the world. Johnson Tiles manufactures a range of glazed porcelain tiles, the first of this type to be manufactured in South Africa.

- Johnson tiles (Olifantsfontein), produces glazed ceramic and glazed porcelain tiles

5.1. CERAMIC MARKETS

There are two main groups of ceramic clays: the dark firing material that is used only in the manufacturing of structural clay products and those materials that are generally fire to a light colour and are used in whitewares. Another distinction is based on the plasticity or workability of the materials, which are broadly defined as plastic, semi-plastic or clays of low plasticity. For the purpose of this report ceramics are split into 4 groups:

5.1.1. WHITEWARES

Each kind of whiteware dictates certain properties that must be met by raw clay material being used. For example porcelain bodies must fired to a pure white colour, stoneware bodies must have good plasticity and firing behaviour, and sanitary bodies must have excellent casting properties. Whitewares include; floor and wall tile, sanitaryware and household ceramics (decorative ceramics, dinnerware etc.).

5.1.2. HOUSEHOLD CERAMICS

The manufacture of household ceramics covers tableware, artificial and fancy goods made of porcelain, earthenware and fine stoneware. Typical products are plates, dishes, cups, bowls, jugs and vases.

5.1.3. STRUCTURAL CLAY PRODUCTS

The most common structural clay products include; bricks, clay pipes, roofing tiles and clay floor and wall tiles.

5.1.4. TECHNICAL CERAMICS

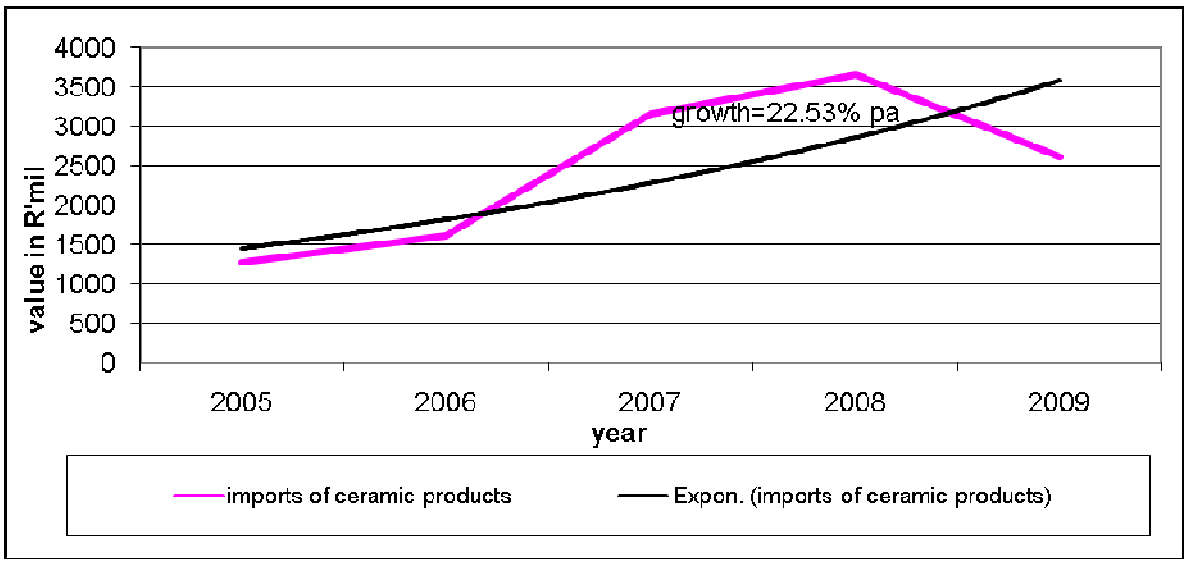
Manufacturers of technical ceramics produce a great variety of products, which are partly based on clays, but also on synthetic raw materials. Like in the other ceramic sectors, the raw materials are fired in kilns.

Advanced ceramics can be:

- Structural – bioceramics, cutting tools, and engine components
- Electrical – capacitors, insulators, intergrated circuit packages, magnets and superconductors
- Coatings – engine components, cutting tools and industrial wear parts
- Chemical and environmental – filters, membranes, catalysts, and catalyst support

The ceramics industry of South Africa is dominated by imports from other countries such as Italy and China. Imports of ceramic products have been growing at an annual rate of 22.5 percent for the past 5 years. In 2008, purchases started declining as a result of the global economic crisis (Fig.10).

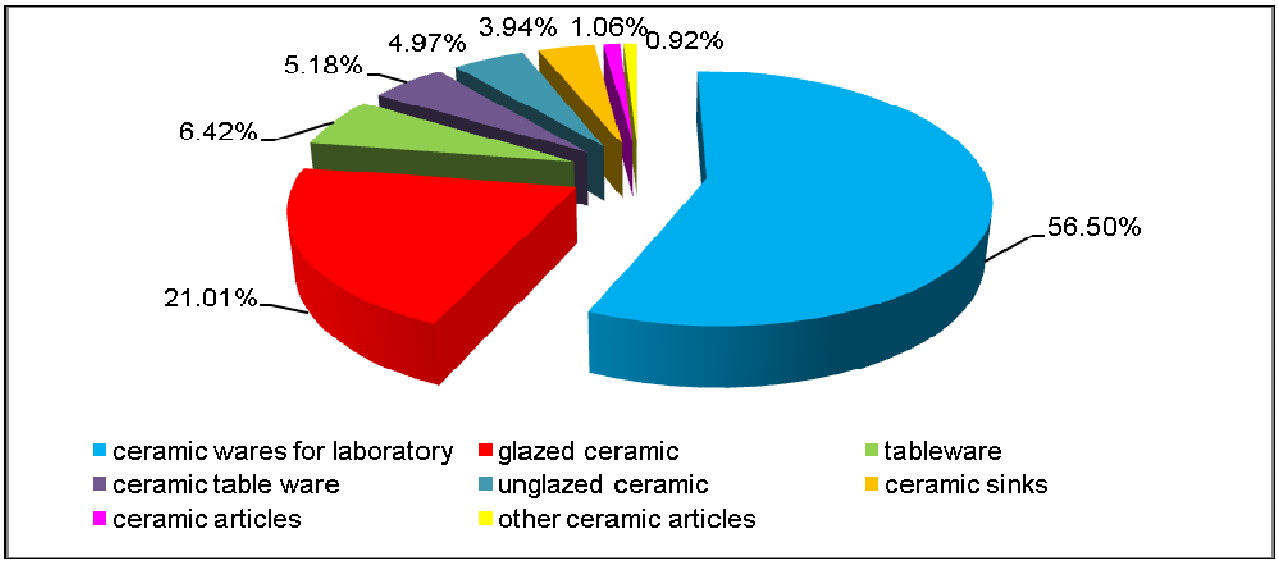
FIGURE 10: SOUTH AFRICA'S IMPORTS OF CERAMIC PRODUCTS, 2005-2009



South African Revenue Services, 2010

In 2009, South Africa imported approximately 183 Mt of ceramic products, worth R2 615 million. Ceramic wares for laboratory accounted for more than 50 percent of the imported ceramic products (Fig. 11).

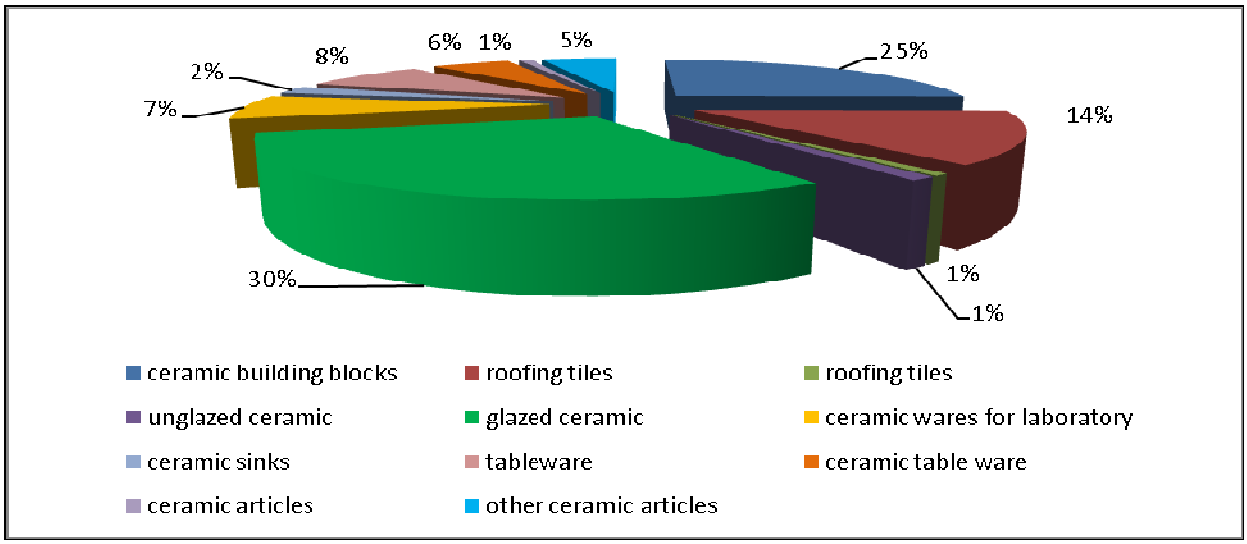
FIGURE 11: SOUTH AFRICA'S IMPORTS OF CERAMIC PRODUCTS, 2009



South African Revenue Services, 2009

South Africa's exports of ceramic products amounted to 15.2 Mt, worth R408 million. Glazed ceramics and ceramic building blocks accounted for 30 and 25 percent of the exported ceramic material respectively (Fig. 12).

FIGURE 12: SOUTH AFRICAN EXPORTS OF CERAMIC PRODUCTS, 2009



South African Revenue Services, 2009

6. ENVIRONMENTAL IMPACTS

Primary environmental issues related to the manufacturing of ceramics include:
1) Gas emission, which may be generated from storage and handling of raw material as well as during firing or spray dying of ceramics. Emissions may also be derived from the raw materials and fuels used for heat and power generation.
2) Waste water, which is generated from cleaning water in preparation and casting units and various other activities such as glazing, decorating, polishing and wet grinding. Potential pollutants include suspended solids (e.g. clays and insoluble silicates), suspended and dissolved heavy metals (e.g. lead and zinc), sulphates, boron, and traces of organic matter.
3) Solid waste, which originates from the manufacturing of ceramic products mainly consisting of different types of sludge, including sludge from waste water treatment, glazing, plaster and grinding activities. Other types of solid waste include broken refractory material, solids from dust treatments, spent plaster moulds and packaging waste.

In order to make sure that pollution is kept at a minimum, ceramic producers comply with various environmental legislations including the Kyoto protocol. The Kyoto protocol is an international treaty of the United Nation Framework Convention on Climate Change (UNFCCC), which aims to stabilize the concentrations of 4 greenhouse gases (carbon dioxide, methane, nitrous oxide and sulphur hexafluoride) and 2 groups of gases (hydrofluorocarbons and perfluorocarbons) that are produced by industrialised countries.

Other mitigation measures include raising environmental awareness amongst employees through the protection policy, conducting environmental impact assessments (EIAs) on all new projects and recycling water back to the environment after all impurities are removed to the environmentally acceptable levels.

7. SMALL SCALE AND BENEFICIATION OPPORTUNITIES

In South Africa, approximately 90 percent of small scale mining (SSM) activities are associated with industrial mineral commodities such as clays, sand, slate and granites, which are mostly used in the production of products for the construction sector. Access to Industrial minerals is less costly because they generally occur closer to the surface. They are easily beneficiated into bricks, ceramics, tiles etc.

These products do not require high levels of skills because they are easily produced. Small scale mining is associated with lack of skills and funding, however there are SOE's (State Owned Entities) such as Mintek and Mining Qualifications Authority (MQA) that assist in training and government departments such as the Department of Mineral Resources (DMR), Department of Trade and Industry (DTI), Industrial Development Corporation (IDC), etc that assist in funding of small scale miners. In-line with the United Nations Millennium Development Goals (MDG's), SSM can be used as a tool to develop the economy by alleviating poverty and creating employment, particularly in rural areas. The DMR is currently monitoring 20 SSM projects and an additional 17 projects are foreseeable in the near future.

Other SSM clay sites are in Newcastle, Northern KZN and QwaQwa in the Eastern Free State where small scale miners dig clay for brick making purposes. These sites produce low quality bricks and require upgrading to enable the Small Medium and Micro Enterprises (SMME's) to access formal markets i.e. government or municipal housing projects.

Ceramic products are produced from feldspar, silica, talc, kaolin and other forms of clay. Examples of SSM projects that produce ceramics include: The Ndwendwe Ceramics, a project based in Kwazulu Natal, initiated to provide employment opportunity to the community of Verulam. A small factory, which beneficiates clay into pottery that is marketable to the western markets, was set up. Sikhululiwe Bawo is a ceramic project based in Matatiele. The project produces ceramics such as plates, ornamental goods and tiles.

8. OUTLOOK

Demand for ceramic products mainly comes from the construction industry, which is one of the largest consumers of industrial minerals. South Africa's abundance of raw material, when combined with cutting edge technology plus research and development could accelerate the growth of the industry and increase its contribution to the national economy. Ceramic raw materials provide a lot of opportunities for small scale mining, particularly in rural areas. Local value addition of these raw materials into ceramics is easy, because it does not require complex skills.

The ceramic industry is expected to improve, as the local construction industry improves. The ceramic market has a strong relationship with the building industry; hence it is expected that sales will increase as the market continues to recover in 2011. The South African construction industry is expected to improve encouraged by the government's R846 million infrastructure development programme from 2010 to 2012. The residential construction market will generate more demand for ceramic tiles.

The non residential sector will see slower growth due to reduction of projects and an expected decline of investment in buildings of an average rate of 5 percent from 2010 to 2012. Advances will mainly be derived from improvements and repairs market, as replacements are made for worn and old floors with tile surfaces. Growth in this sector will be slow owing to the fragile local and global economic recovery.

New entrants into the industry, particularly small scale manufactures are having difficulty competing in formal markets due to lack of finance, because of the constant increase in raw materials and production cost. Most funding for small scale producers comes from government; however this is not enough to sustain their growth. The much needed support from the private sector in the form of joint venture projects and transfer of skills and technology development would help in facilitating the participation of small scale manufacturers in formal markets.

Innovation will play a crucial role in the recovery of this sector. Present production technologies allow for all new and alternative uses of ceramics. Future growth markets in South Africa include ceramic filters, membranes, fuel cell technologies,

armour protection/ bullet proofing, ceramic protective linings, high-tech specialties (e.g. industrial diamond convolutes) and ceramic fibre products.

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