REPORT R89/2010

REFRACTORY CLAYS INDUSTRY IN THE REPUBLIC OF SOUTH AFRICA, 2010

DIRECTORATE: MINERAL ECONOMICS

mineral resources

Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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1. INTRODUCTION

The aim of this report is to reflect on the overview of the clays industry in South Africa, with particular focus on refractory clays, namely fire clay and flint clay.

The term refractory clay is used for any kaolinitic clay which has a fusion temperature in excess of 1 605 ^{o}C and which is suitable for use in the manufacturing of refractory products. These clays are of sedimentary origin and are often associated with coal measures in their geological settings. Underground mining is required because much of higher quality clay occurs at great depths and overlying rocks are too hard to strip. Refractory clays consist essentially of hydrated aluminium silicates with minor proportions of other minerals (Horn and Strydom). Technically, refractory clay is any clay showing or having a pyrometric cone equivalent (PCE) of not less than cone 27.

Refractory clays are deficient in iron, calcium and alkali metals and they may range from laminated (plastic) to entirely non-plastic (flint-varieties) depending on their bulk densities. The properties that determine the use for which the refractory clays may be suitable are refractoriness and plasticity. A useful system was developed by Vereeniging Refractories Ltd for classifying refractory clays (Bredell 1987). The system was based on two parameters of refractory clays, their bulk density and alumina contents (on a calculated basis). The alumina content gives a good indication of the purity and refractoriness of the clay, while bulk density reflects its plasticity (Bennets 1965).

Refractory clays are used in a variety of applications, such as making firebricks and blocks, insulating bricks, saggers, refractory mortars and mixes, monolithic and castable materials, ramming and air gun mixes, and other products (Harvey et al.).

The common feature is that refractory clays contain kaolinite as the main mineral phase, and their composition is 20-45 percent Al_2O_3, <3 percent Fe_2O_3, <3 percent $Na_2O + K_2O$. According to USGS, types of refractory clays include: fire clay, plastic and semi-plastic clay, refractory kaolin (usually bauxite), flint and semi-flint clay and chamotte.

2. OCCURENCES

Fire clay is sometimes subdivided into plastic and semi-plastic fire clays and flint and semi-flint clays. The plastic and semi-plastic fire clays are plastic, low in iron and alkalis and have a PCE of 26-33. The flint and semi-flint clays are hard, have a conchoidal cleavage, won't slake in water, and have a PCE of 33-35. The aluminium content of refractory kaolin and fire clays differ; refractory kaolin contains more aluminium than fireclays. In general, the aluminium oxide content of refractory kaolins generally is in the high 50 to 70 percent. Fire clay usually contains less than 50 percent aluminium oxide.

Most fire clays occur in sedimentary rocks and deposits range in age from Pennsylvanian to Tertiary. Deposits of this age occur as under clays (seat earth) immediately below or closely associated with coal beds and others have apparently been transported and deposited in local basins in a near shore, swamp or flood plain environment (Pickering et al.).

Flint is interpreted as having been a product of very early digenesis that occurred mainly during accumulation of parent aluminium silicate material rather than dominantly after its deposition and consolidation. The depositional environment typically was non-marine, paludal or fluviatile, at a time of local crystal stability, within the environment and climate typical of coal measures. Very high alumina diaspore bearing flint clays are sources of refractory materials in Scotland, South Africa, Israel and China (AAPG/Datapages, Inc. DOI Citation).

Refractory clays are produced in many countries; however the information available to the authors on worldwide production is sketchy and incomplete. This is partly because the distinction between fire clay and miscellaneous clay is not made in some countries and clay used for refractory products is lumped with kaolin in others. Those countries include United Kingdom, the former West Germany and Japan. In nature, refractory clay is usually found to contain 24-32 percent Al_2O_3, 50-60 percent SiO_2 and loss on ignition (LOI) between 9 to 12 percent. Impurities like oxides of calcium, iron, titanium and magnesium and alkalies are invariably present, making it white, grey and black in colour.

Other producers of refractory clays are China, Czech Republic, France, Germany, Poland, South Africa, Spain and Ukraine. In South Africa, most occurrences of refractory clay are restrained to the Vryheid Formation of the Ecca Group of the Karoo Supergroup. Flint clays roughly dominate north of 26^o S latitude. These deposits are found in two provinces in South Africa. In Gauteng province, they are found in the Modderfontein farm in the east rand, west rand and Hammanskraal in Pretoria and in Mpumalanga province, at Nooitgedacht, which is situated 20 km north of Bronkhorspruit.

In Gauteng province, the refractory clays resources are found in the East Rand, West Rand and Pretoria-Hammanskraal area. The estimated East Rand inferred clay resources are as follows:

- indicated resources of semi-flint and plastic clay with a good refractoriness: 10.5 Mt;
- indicated resources of semi-flint, semi-plastic and plastic clay with a good refractoriness: 11.3 Mt;
- indicated resources of semi-flint, semi-plastic and plastic clay with a low refractoriness: 22.4 Mt and
- refractory clay sterilized by urban development (as at 1987): ≈26.6 Mt.

Total inferred resources of refractory on the West Rand could be in excess of 200 Mt of which 70 percent can be expected to consist of clay with good refractoriness, 27 percent of clay with a low refractoriness and 3 percent of non-refractory clay.

Pretoria-Hammanskraal conservative probable ore reserves of flint clay were estimated to be of the order 1 to 2 Mt, but underground mining could increase the figure to over 50 Mt (Bennets 1965). However, the industry estimated the proven reserves of high-quality flint clay at about 3.5 Mt, with additional estimated reserves of about 4 Mt (Heckroodt). For estimation of resources refractory clays grouping was done in three categories:

- Grade I flint clay: demonstrated resources of 15.2 Mt, of which 3.4 Mt represented measured reserves under prevailing conditions; inferred resources of 1.0 Mt;
- Grade I semi-flint and Grade II and III flint clay: demonstrated resources of 4.6 Mt; inferred resources of 1.0 Mt and
- Grade I to III plastic clay: demonstrated resources of 1.2 Mt; inferred resources of 0.5 Mt.

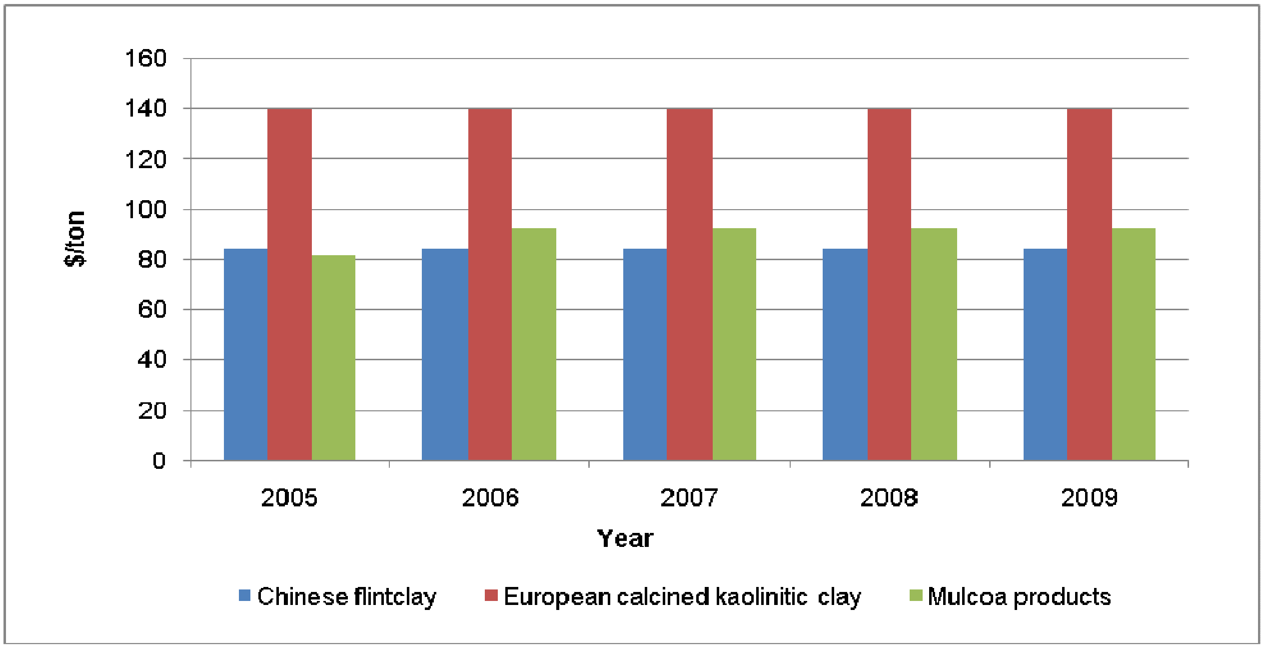
In the Mpumalanga province, refractory clays are exploited at Nooidgedacht and Rietfontein. The total resources of refractory clay in Rietfontein amount to 15 Mt and the area appears to have tremendous potential. The indicated resources for Nooidgedacht flint clay is 14.3 Mt (Bredell 1987).

3. WORLD PRICES

For the past five years, Chinese flint clay prices have been constant at $84/t, while European calcined kaolinitic clay price was also constant at $140/t. Mulcoa (sintered mullite with high alumina content) products price was at $81.84 in 2005, but went up to $92.75 in 2006. From 2006 to 2009, Mulcoa products prices remained constant at $92.75 (Fig. 1). Prices were stable for the past five years.

Please Note: Prices are rarely published for fireclay because of differing classification of raw materials.

FIGURE 1: REFRACTORY CLAYS PRICES, 2005-2009



Source: Industrial Minerals, 2005-2009

4. WORLD SUPPLY AND DEMAND TRENDS

Supply exceeds demand because of the poor market conditions resulting from the 2008/2009 recession. Consequently, there may continue to be some excess production capacity for fire clay in the future. That is less true for refractory kaolin grades. Refractory plants were mothballed around the world owing to declining demand from steel and aluminium producers. Production declined owing to lower demand for fire clay for the manufacture of products used by the building market. Also demand from the construction industry for heavy-clay products manufactured using fire clay declined.

Five years ago the refractory clay market was robust owing to the strong performance of the steel market. But during 2008, the market collapsed owing to the recession. The current world market for refractory clays continues to be affected by the downturn in the world economy. The worldwide recession and specifically the downturn in the steel production in North America and Europe have impacted the market the most. The US and European markets started to slow down, followed by China later. However, even though the refractory clay market seems to have been less impacted upon compared to the overall family of refractory raw materials, it has nevertheless suffered since then and is still recovering slowly.

Decreasing production of fire clay was influenced by the following factors:

- the development of more durable aluminous refractory minerals (andalusite, bauxite, zirconia etc.);
- shift to the basic oxygen process in steel making, which requires basic rather than alumina-type firebrick in furnaces and;
- changes statistical reporting, where fire clay used in light-coloured facebrick, stoneware and ceramic products is now classified as miscellaneous clay rather than fire clay.

5. SOUTH AFRICAN REFRACTORY CLAYS

There are a number of terms used to describe refractory clays; the most common are fire clay, flint clay (also known as hard clay), plastic clays (also known as ball clays) and kaolins. In South Africa only fire clay, flint clay and kaolins are produced, but for the purpose of this report focus will be on fire clay and flint clay.

5.1. DEFINITION

5.1.1. FIRE CLAY

Fire clay is siliceous clay rich in hydrous aluminium silicates, capable of withstanding high temperatures without deforming, disintegrating or becoming soft and pasty. It is deficit in iron, calcium and alkalis and approaches kaolin composition, and the better grades containing at least 35 percent Al_2O_3 when fired (Fig.2, 3, 4 & 5).

Fire clay is normally a plastic to semi plastic clay used to cover ladles and used as plugs. It is also used in many other refractory applications. It is often used as a plasticing agent (make plastic) when making the refractory cements.

FIGURE 2: FIRE CLAY LOCATION

Source: traditional oven.com

FIGURE 3: FIRE CLAY ROCK

Source: mineralszone.com

FIGURE 4: FIRE CLAY STOCKPILE

Source: traditional oven.com

FIGURE 5: FIRE CLAY

Source: traditional oven.com

5.1.2. FLINT CLAY

Flint clay is a smooth, flint like refractory clay rock composed dominantly of kaolin, which breaks with a pronounced concoidal fracture and resists slaking in water. It becomes plastic upon prolonged grinding in water (Fig.6, 7 & 8).

Flint clay is a non-plastic clay normally fired after mining in clamp kilns to 1000^oC to make chamotte from which refractory products are made, such as bricks. Both fire and flint clay will have Al_2O_3 contents in access of 42 percent measured on a calcined basis and up to approximately 39 percent on non-calcined basis.

FIGURE 6: FLINT CLAY

Source: ec21.com

FIGURE 7: FLINT CLAY

Source: qdyxk.com

FIGURE 8: FLINT CLAY STOCK PILES

Source: diytrade.com

5.2. PRODUCTION PROCESSES AND MARKETS

Fire clay is usually mined at depth, usually found in seat earth (under clay) associated with coal measures. The processing of fire clay is the same as all the clays except the different drilling and testing procedures are required. Drilling ordinarily requires diamond bits and core barrels similar to the type used for the minerals in hard rock. The most common test in evaluating fire clay is determining the PCE (Fig.9 & Fig.10).

A good fire clay should have 24-26 percent plasticity and shrinkage should be within 6-8 percent maximum after firing. It should also not contain more than 25 percent Fe_2O_3. Refractoriness and plasticity are the two main properties needed in fire clay for its suitability in the manufacture of refractory bricks. A good fireclay should have a high fusion point and good plasticity. Depending upon their capacity to withstand high temperatures before melting, the fireclays are graded into the following:

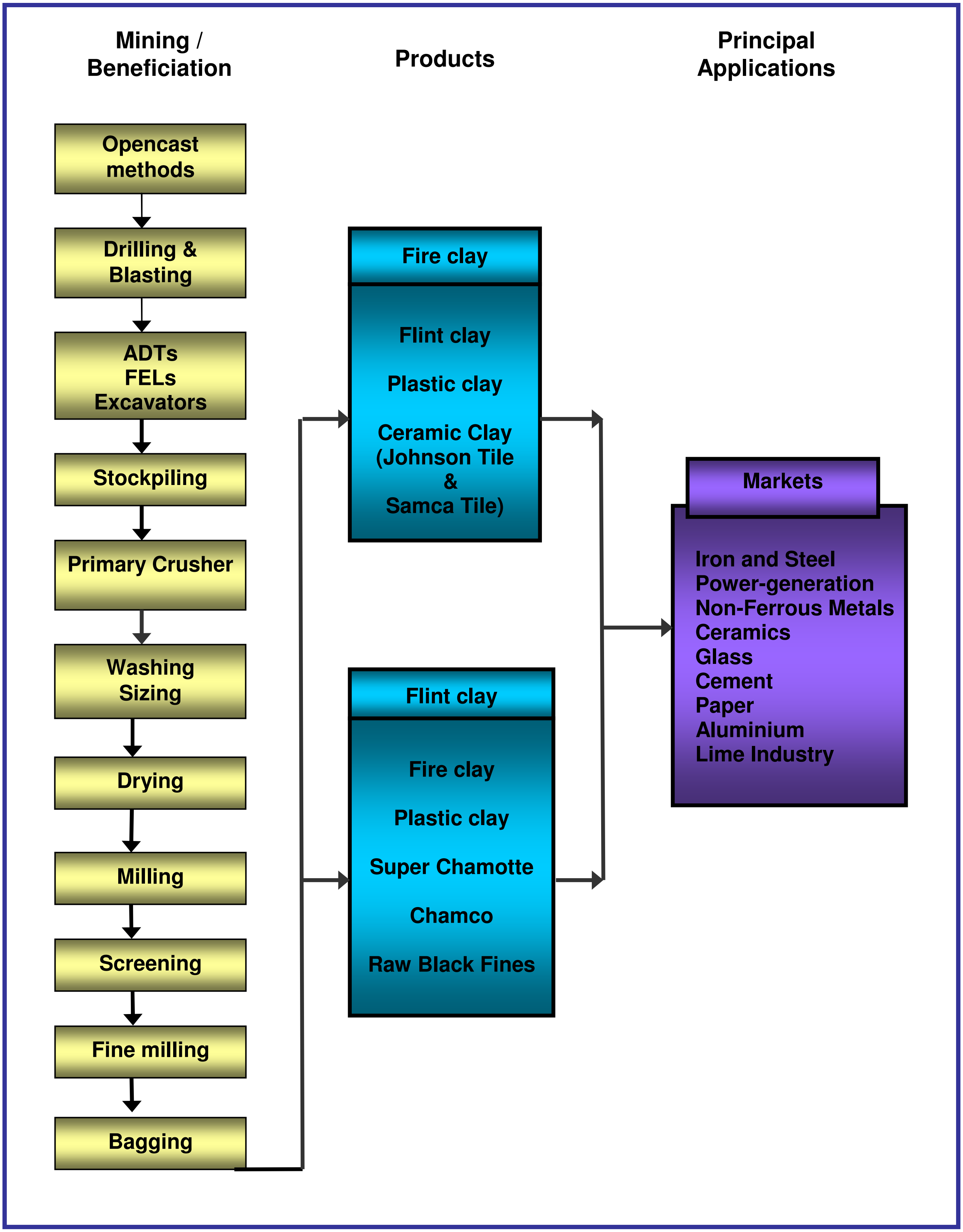
- Low duty - withstand temperatures between 1515-1615℃ (PCE 19 to 28)
- Intermediate duty - 1650℃ (PCE 30)
- High duty - 1700℃ (PCE 32)
- Super duty - 1775℃ (PCE 35)

(Mineralszone.com)

The refractory clay industry depend on the health of various industries including the aluminium, iron and steel, power-generation, ferrous and non ferrous metals, ceramics, cement, glass, lime and acid industries, which are the major drivers for demand of refractory clays (Fig.9 &10). Refractory clays are mainly used in furnaces, kilns, boilers, ovens, casting pits, crucibles and nozzles. Industrial importance of refractory clays includes: manufacture of tiles for walls, floor coverings, porcelain, china (hard, white, translucent pottery with soft glaze) and earthenware (common ceramic material, which is used extensively for pottery tableware and decorative objects) and pipes for drainage and sewage. In other instances, refractory clay may form most of the bodies of the brick, tile etc. Generally, using fireclay for common clay applications is not desirable because of the lower market prices for those applications.

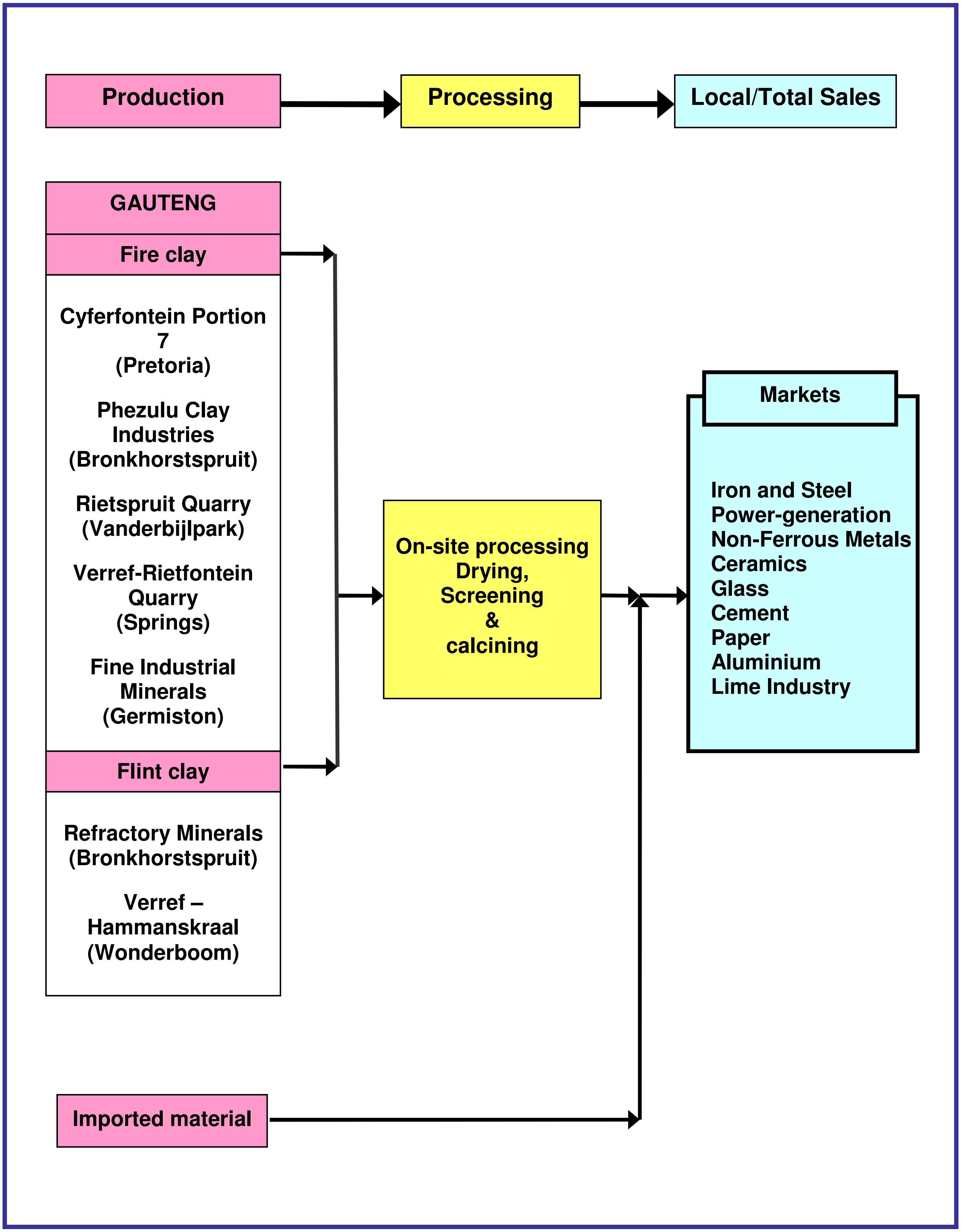
The refractory clay market varies in accordance with general economic activity and is dependent on both normal consumable demand as well as demand from new projects.

FIGURE 9: SOUTH AFRICA'S FIRE CLAY AND FLINT CLAY INDUSTRY FLOWCHART



Source: DMR Mineral Economics

FIGURE 10: SOUTH AFRICA'S COMPANY STRUCTURE OF FIRE CLAY AND FLINT CLAY

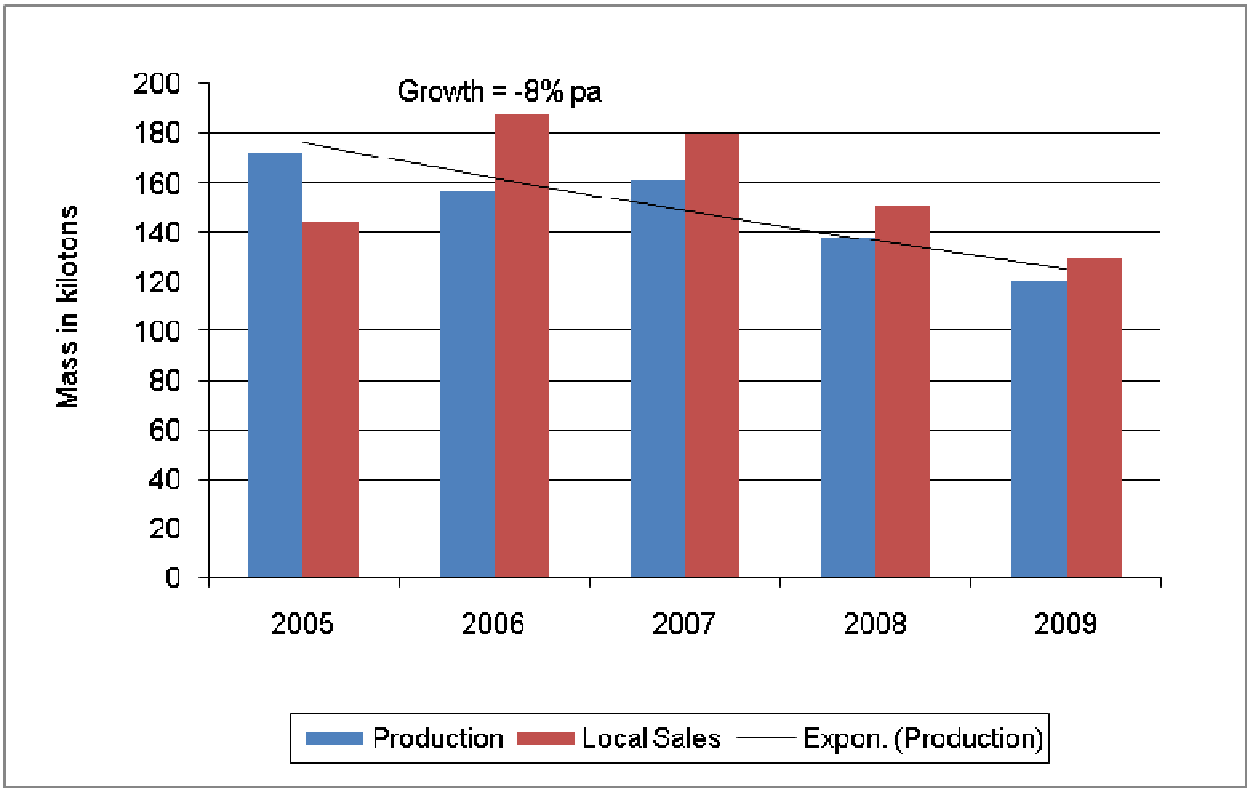


Source: DMR Mineral Economics

5.3. Supply and Demand Trends

South Africa's production of fire clay decreased by an average annual rate of 8 percent over the last 5 years to 120.1 kt in 2009, owing to the impact of recession and the availability of alternative, higher alumina raw materials such as andalusite (Fig.11). The decrease in production was further exacerbated by some fire clay mine's inability to produce the required grade for the market. Local sales mass decreased by an average annual rate of 4 percent from 2005 to 2009, due to lower demand for products containing fireclay (Fig.11).

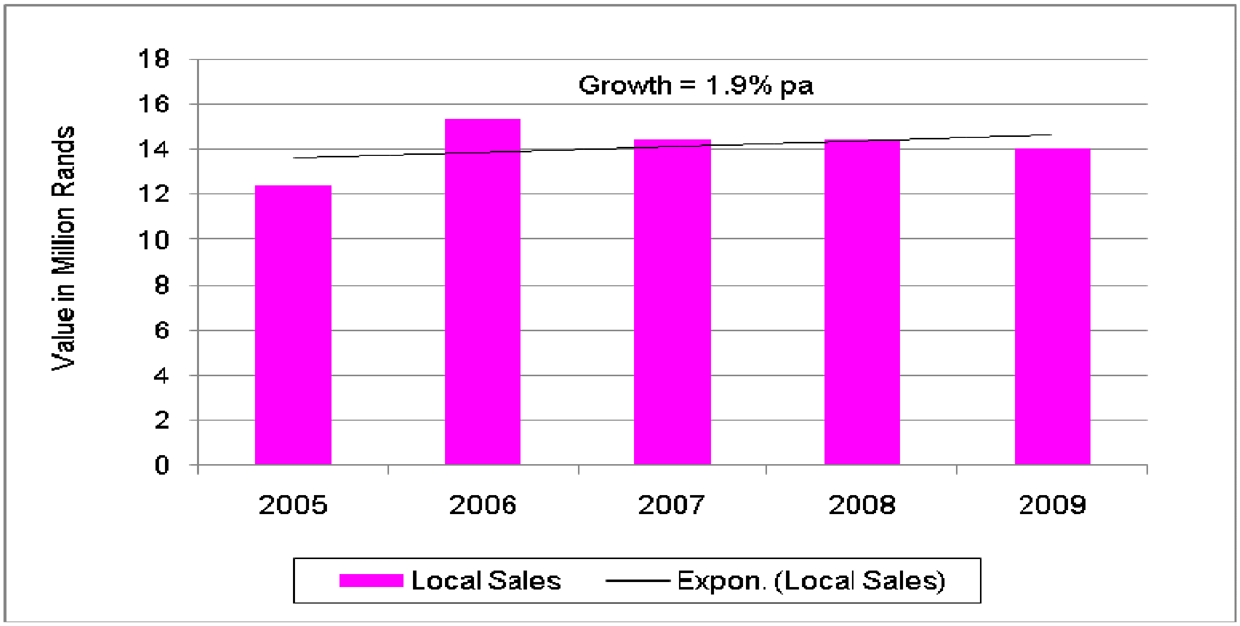
FIGURE 11: SOUTH AFRICA'S SALES OF FIRE CLAY BY VOLUME, 2005-2009



Source: DMR Mineral Economics

South Africa's local sales value of fire clay increased by an average annual growth rate of 1.9 percent between 2005 and 2009 (Fig.12). No export sales were recorded for fireclay for the past five years as demand from China, North America and Europe dried up. Demand for fire clay varies according to overall refractory market, which in turn is related to the general industrial level of output and demand.

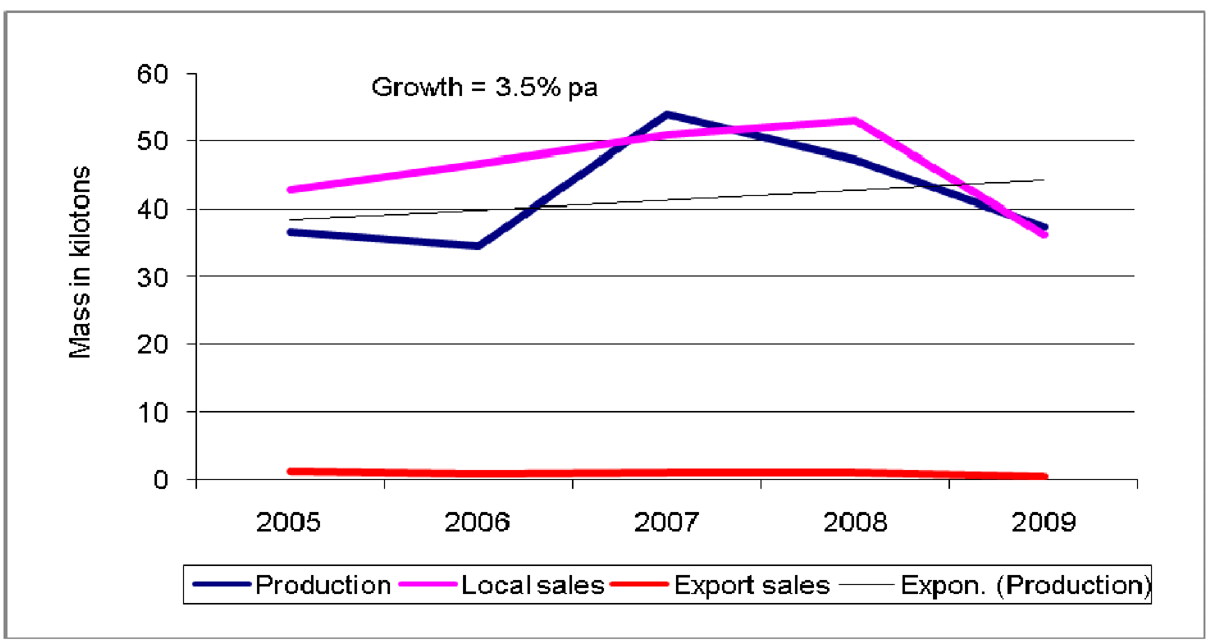
FIGURE 12: SOUTH AFRICA'S FIRE CLAY SALES BY VALUE, 2005-2009



Source: DMR Mineral Economics

DMR statistics indicate that flint clay production growth for the past five years went up by 3.5 percent to 37.2 kt in 2009 (Fig.13). However, local sales mass declined by 2 percent from 2005 to 2009 due to the effects of economic downturn (Fig.13). Export sales mass dropped by an annual average rate of 14 percent to 0.5 kt in 2009 (Fig. 13).

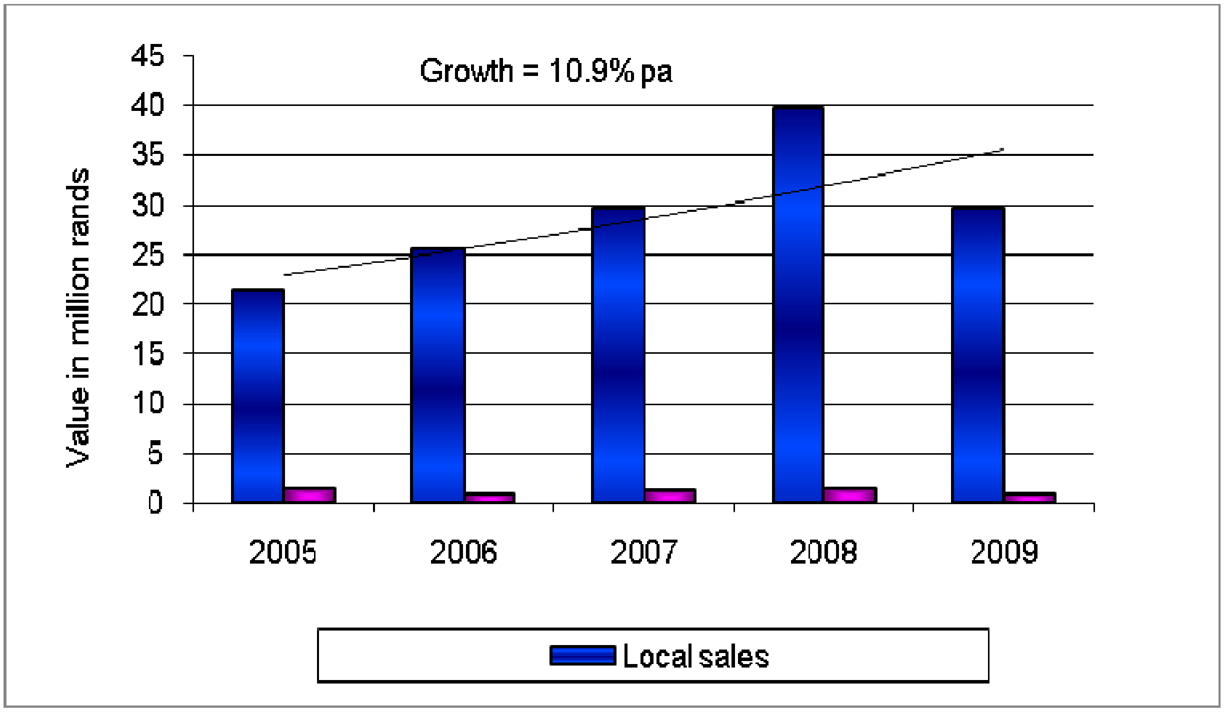
FIGURE 13: SOUTH AFRICA'S FLINT CLAY SALES BY VOLUME, 2005-2009



Source: DMR Mineral Economics

Local sales value increased by 10.9 percent from 2005 to 2009 as the industry slowly recovered from the effects of the economic crisis. In 2008, sales value reached R39.7 million as the result of commodity boom (Fig.14). Export sales value declined by an annual rate of 3 percent during the period under study (Fig.14).

FIGURE 14: SOUTH AFRICA'S FLINT CLAY SALES VALUE, 2005-2009

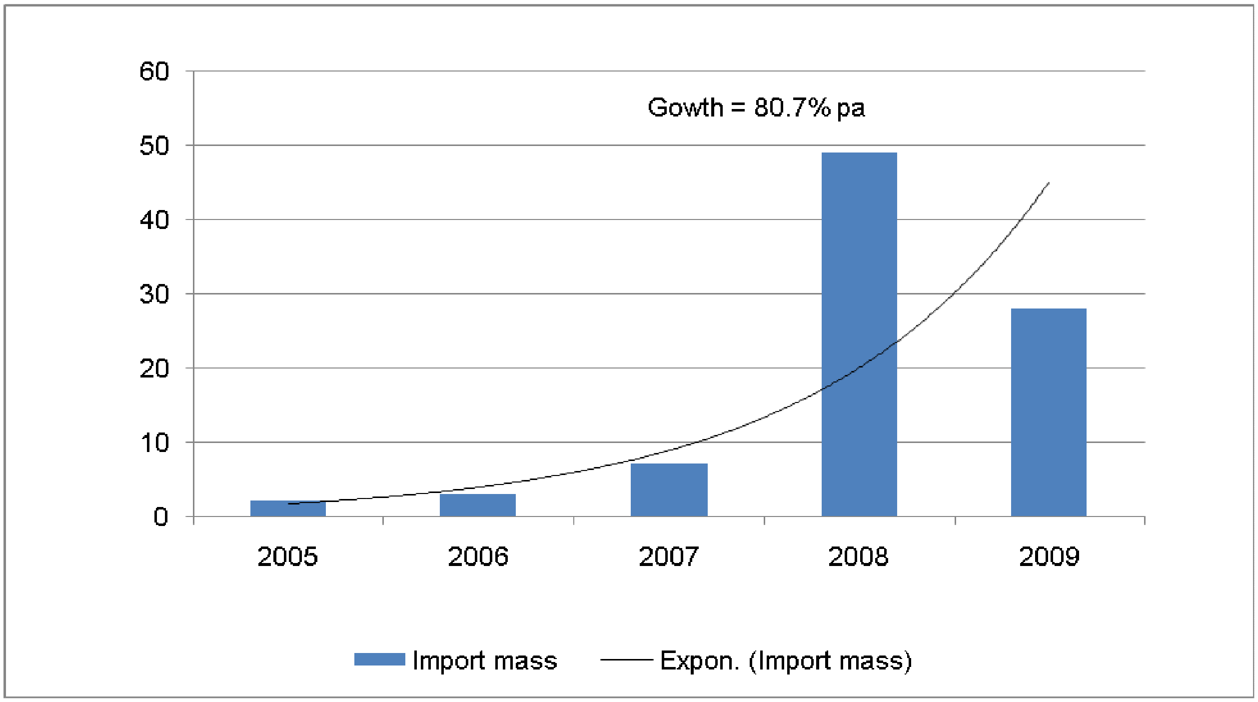


Source: DMR Mineral Economics

5.4. South African Trade

South Africa's imports of fire clay increased at an annual growth rate of 80.7 between 2005 and 2009 due to cheap Chinese imports (Fig.15). The South African industry is basically self-sufficient, with no real evidence of imported material making any sort of impact. The main reason for this is that the majority of consuming industries are located on the reef, and the cost of freight from either Durban or Richards Bay effectively adds up on the overall price, thereby reducing the cost competitiveness of imports.

FIGURE 15: SOUTH AFRICA'S FIRE CLAY IMPORTS, 2005-2009



Source: SARS

6. DEVELOPMENTS IN THE INDUSTRY

In April 2005 Vereeniging Refractories (Verref) established a research and development (R&D) department that could more accurately be described as a research, development, test and evaluation department. The scale of investment in R&D is illustrated by the fact that the department has both an X-ray diffraction (XRD) and an X-ray fluorescence (XRF) machine, plus a workshop, a pilot plant for new products and a quality-control section. Refractories must withstand both high and chemical attack, the latter comes from the slag in the smelters. The R&D department tests the client's slags at rotary slag-testing machine with their refractories and in this way it is possible for the company to determine exactly how and to what degree the different slags attack its products. This puts the department in the position to make expert recommendations to customers regarding which of their products work best with their slags. Other tests undertaken include testing the strength of refractory bricks at high temperatures.

7. SMALL SCALE MINING AND BENEFICIATION OPPORTUNITIES

Refractory clay deposits are commonly lenticular and display unpredictable lateral variations in both composition and physical properties, often within the same bed, which makes grade control difficult during exploitation. Unless the characteristics of a deposit are well known and defined through detailed exploration, it might therefore be difficult for small, inexperienced miners to mine without additional technical input. Also, the beneficiation processes of some types of refractory clay can also be a fairly technical process, which might not fall within the technical capabilities of a small miner. Small Scale Mining is very labour intensive because of hand sorting of the clay before and after firing.

8. CONSTRAINTS IN THE REFRACTORY CLAYS SECTOR

The availability of high grade and very high grade refractory clays at competitive cost is one of the long series problems faced by the refractory industries. Deposits of very high grade diaspore clay in Pennsylvania and Missori that can be mined by stripping methods are nearing exhaustion and underground mining increases costs considerably. The cost of underground mining is one of the reasons why production of refractory bauxitic and kaolinitic clay has increased, and this generates constraints as the two are the competitors of refractory clays.

In South Africa the technical process for refractory or fire clay is very difficult and financially extremely expensive for other companies due to the increase in energy consumed to bake or vitrify (to change or make into glass or a glassy substance, especially through heat fusion) the products. The other reason is that other companies don’t have production kilns of temperature greater than 1200 ^{o}C.

9. OUTLOOK

The refractory industry is limited due to technologies in the steel industry that have changed to magnesite and graphite as well as mixtures of these two commodities (i.e. refractories have moved away from acid types to more basic types).

The refractory clay industry has certainly decreased at a lower pace. For the next four years, it is forecasted that demand for refractory clays will recover, owing to the rarity and the cost competitiveness of raw materials from China. One of the favourable factors would certainly be the major increases in higher alumina raw materials prices for the refractories market.

Current outlook is that at best the demand for fire clay will stay as is. Much of the demand from Zambia and Democratic Republic of Congo (DRC) fell after economic crisis as new cobalt and copper projects were postponed, demand is expected to recover when these projects are restarted.

While healthy steel markets have supported refractory clay consumption previously, rising energy costs are squeezing the producers' margins. The outlook for refractory clays is not as bright as it could be, despite the recovery in the industries that consume these clays owing to competition with non-clay products in the refractory market. About 60-70 percent of world andalusite production, of which South Africa accounts for 70 percent, ultimately goes into the iron and steel industry. Use of andalusite in the iron and steel industry therefore, tends to reduce local refractory clays market in that industry. Other challenges include unavailability of high grade and very high grade refractory clays at competitive costs as well as the stagnant prices. However refractory clays are still basic and viable commodities, important in many industrial processes requiring elevated temperatures.

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