REPORT R82/2009

GYPSUM IN SOUTH AFRICA

DIRECTORATE: MINERAL ECONOMICS

mineral resources

Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

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Compiled by: M Nevondo

Email: mbavhi.nevondo@dme.gov.za

Issued and obtained from

The Directorate Mineral Economics, Mineralia Centre,

234 Visagie Street, Pretoria 0001, Private Bag X59, Pretoria 0001

Telephone (012) 317- 8538, Telefax (012) 320 4327

Website: http//www.dme.gov.za

DEPARTMENT OF MINERAL RESOURCES

Director-General Adv. S. Nogxina

MINERAL POLICY AND PROMOTION BRANCH

Acting Deputy Director General Mr. M. Mabuza

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DIRECTORATE: MINERAL ECONOMICS

Acting Director Ms. N. Dlambulo

Acting Deputy Director: Industrial Minerals Mr. D. Naidoo

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1. INTRODUCTION

Calcium sulphate occur in nature as two well-defined minerals: gypsum ($CaSO_4.2H_2O$) or as anhydrite ($CaSO_4$). Calcium sulphate minerals occur all over the world in large deposits. The clear, crystalline variety of gypsum is known as selenite while the massive, granular, marble-like form is known as alabaster.

Gypsum and anhydrite are the hydrated and anhydrous forms of calcium sulphate, which occur in nature as evaporate deposits in the form of nodular masses or beds up to a few metres thick. Gypsum is formed by the hydration of anhydrite at or near surface, but usually passes into anhydrite below 40 to 50 metres. Porous limestone, white sediments, dolomite and anhydrite are usually associated with gypsum deposits.

Gypsum is also produced as a by-product of manufacturing processes, and is named synthetic gypsum. Synthetic gypsum is recovered during the manufacture of phosphoric acid or as a result of treating waste. The only countries using significant amounts of synthetic gypsum are Japan and West Germany. As it becomes more difficult to obtain permission to dump synthetic gypsum, more of it may be used in building materials. Currently, synthetic gypsum does not have any economic advantage over natural gypsum, mainly because of the impurities it contains.

2. WORLD

2.1 OCCURENCES

Both gypsum and anhydrite form through the evaporation and concentration of marine brines in the environments ranging from the bottom of the basins to the top of salt domes. Once formed, gypsum may be buried and so convert to anhydrite, which hydrates back to gypsum when uncovered by erosion.

The main gypsum reserves are in Canada estimated at 1,3 billion tons, followed by the United States at 700 million tons and China at 450 million tons. Gypsum resources are adequate but unevenly distributed.

Synthetic, chemical or by-product gypsum is increasingly available, i.e. chemically manufactured gypsum and generally a by-product created during various manufacturing, industrial or chemical processes. Common examples include the process of flue gas desulfurization (FGD gypsum) or during the production of phosphoric acid (termed phosphogypsum), hydrofluoric acid (fluorogypsum), titanium dioxide (titanogypsum), and citric acid (citro gypsum)

2.2 PRODUCTION PROCESS

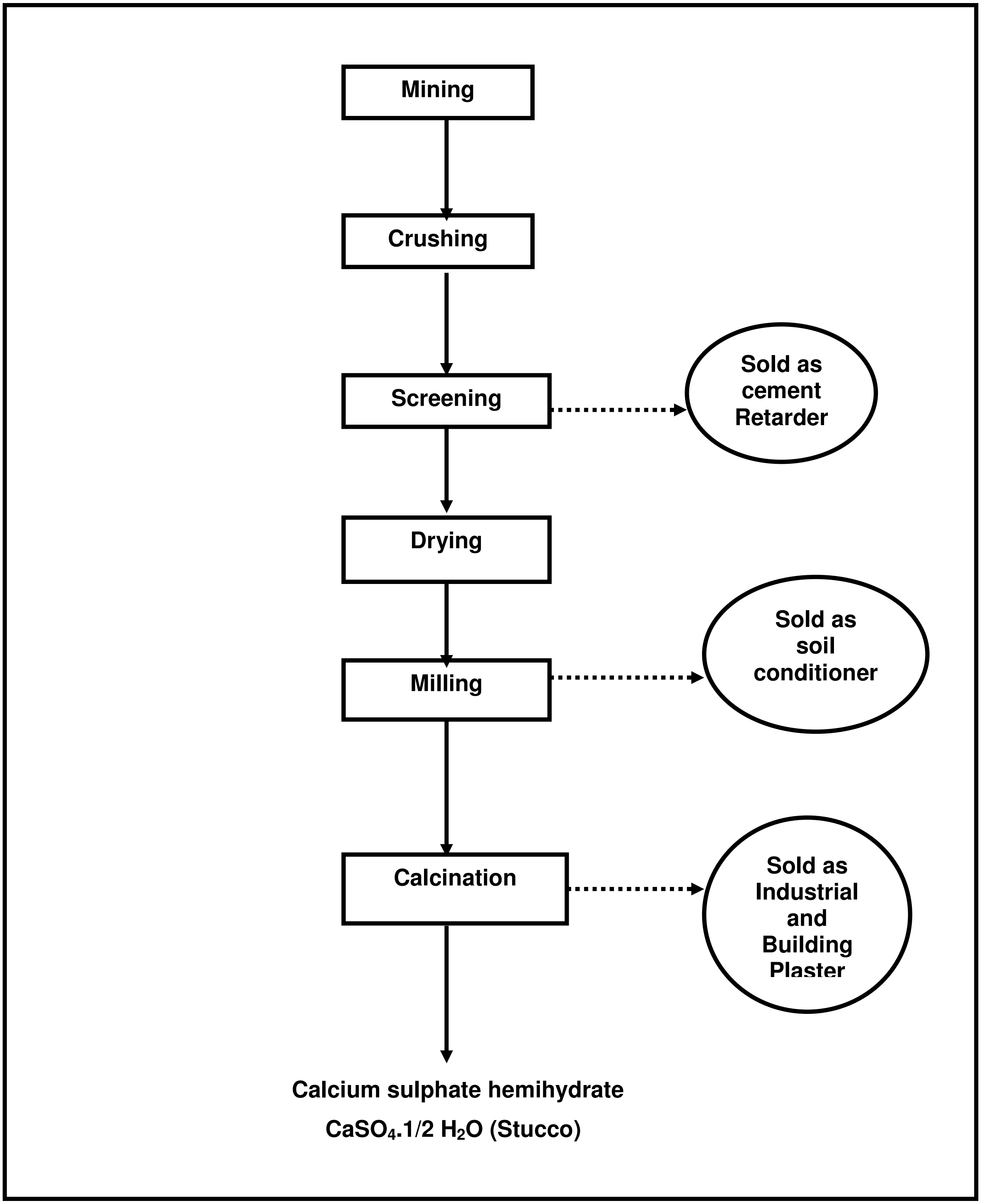
Gypsum is mined both from open pit drill and blast system and also underground mining. The most common form of gypsum mining worldwide is open pit mining. A flow diagram for a typical gypsum process producing both crude and finished gypsum products is shown in Fig. 1. Raw gypsum ore is processed into variety of products such as portland cement additive, soil conditioner, industrial and building plasters and gypsum wallboard.

In this process gypsum is crushed, dried, ground and calcined. The major use of calcined gypsum is in plasterboard. Other uses include joint filler, desiccant and mould making for pottery, sanitary ware and metal casting. Not all of the processing stages shown in Fig. 2 are performed at all gypsum plants. Some plants produce only wallboard and many plants do not produce soil conditioner.

The processing of gypsum depends on the end use. There is little or no beneficiation. Nearly all-commercial gypsum is calcined. Generally gypsum is ground, calcined at 250^oC for 2 hours and then at 300-350^oC, when it loses 75% of its water of crystallization and forms the hemihydrate ($CaSO_4$. ½ H_2O), known as plaster of Paris, stucco or plaster. On addition of water to plaster it rehydrates to form a physical structure in which the unhydrated gypsum and water are embedded, which on drying and setting forms a rock hard, fire resistant material.

Uncalcined gypsum is used in the manufacture of cement (3-6% added to clinker controls the setting time of cement), in soil treatment for agricultural purposes, as filler, in food and pharmaceuticals and as a flocculent.

FIGURE 1: OVERALL PROCESS FLOW DIAGRAM FOR GYPSUM PROCESSING

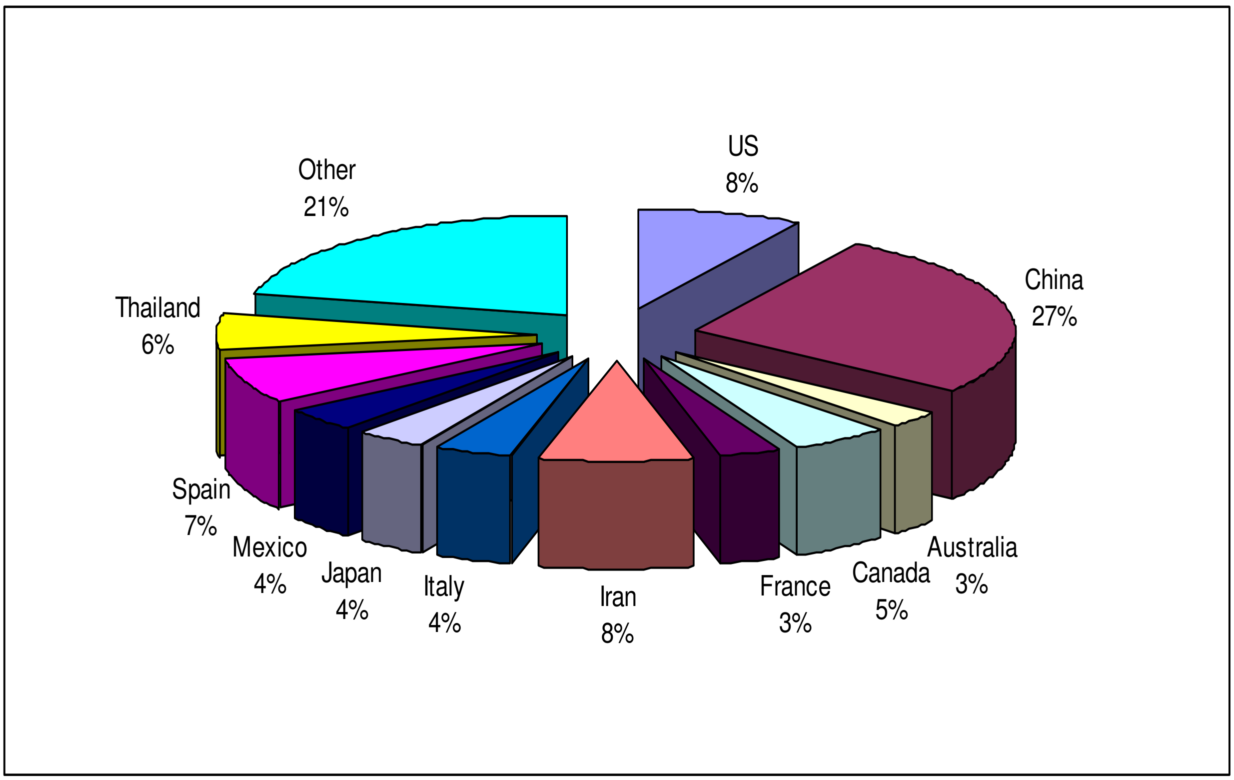


Source: DME, Directorate Mineral Economics

2.3 WORLD PRODUCTION/ SUPPLY

World gypsum production is estimated to have amounted to 151 Mt in 2008. China was the world's leading producer of gypsum in 2008, accounting for 27 percent of the world total gypsum output, followed by the US and Iran, both at 8 percent and Spain at 7 percent.

FIGURE 2: WORLD PRODUCTION OF NATURAL GYPSUM BY COUNTRY, 2008

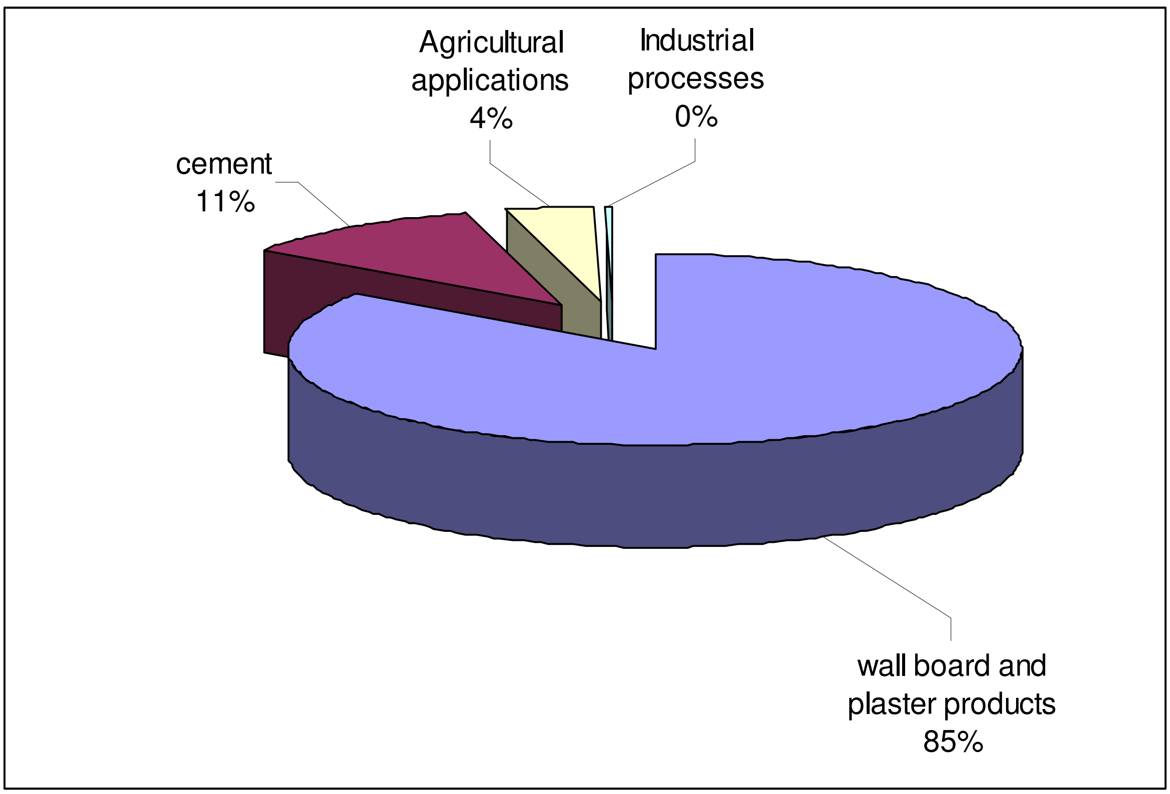


Source: USGS, 2008.

2.4 WORLD DEMAND

Demand for gypsum depends mainly on the strength of the construction industry, particularly in the United States (US), with manufacturers of wallboard and plaster products accounting for 85 percent, 11 percent for cement production, 4 percent for agricultural applications and small amounts of high-purity gypsum for a wide range of industrial processes, such as smelting and glassmaking.

FIGURE 3: GYPSUM CONSUMPTION IN THE UNITED STATES, 2008



Source: USGS, 2008

2.5 WORLD TRADE

Gypsum is widely available and is considered a low cost commodity and consumed close to the point of production. The major exporters of gypsum are: Canada, Mexico, Spain, Thailand, Germany and Australia. The major importers of gypsum are: Belgium, Denmark, France, India and Japan.

2.6 WORLD PRICES

In view of the very limited international trade in gypsum, and the fact that by far the greater part of the world's crude gypsum is not sold as such but is calcined by the producers, prices for the mineral are not published nearly so frequently as in the case of most other industrial minerals.

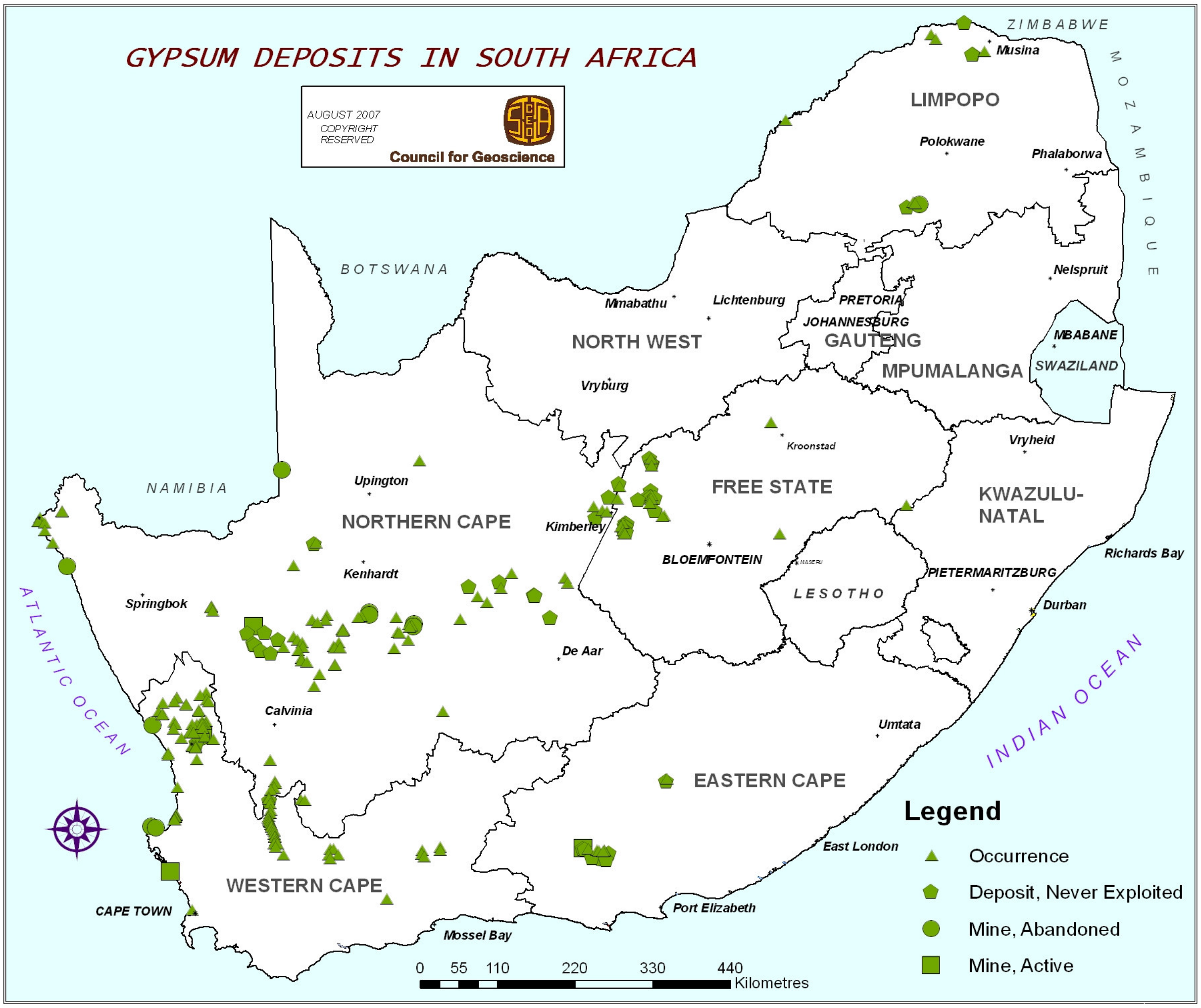
However, the US average price for crude gypsum, free on board (f.o.b), and calcined gypsum, f.o.b. plant was $7.25/ton and $17/ton respectively in 2008.

3. SOUTH AFRICA

3.1 LOCATION AND TYPE OF GYPSUM MINES IN SOUTH AFRICA

The South African gypsum production sites are shown on Figure 4. The Dikpens mine in Calvinia at the Northern Cape, and the Mount Stewart mine in Jansenville at the Eastern Cape, all occur in the Whitehill formation of the Ecca Group, within the Karoo Supergroup of rocks. The Geelvloer Gips in the Kernhardt area of the Northern Cape and the Kolkies Rivier mine in the Ceres area of the Western Cape. The Maskam mine in the Van Rhynsdorp area of the Western Cape, mines powdery gypsum and crystal aggregates from clays along dry water courses. The Yzerfontein deposit (Darling area, Western Cape) is unique in that the gypsum is dredged from a coastal pan.

FIGURE 4: OCCURRENCE OF NATURAL GYPSUM IN SOUTH AFRICA

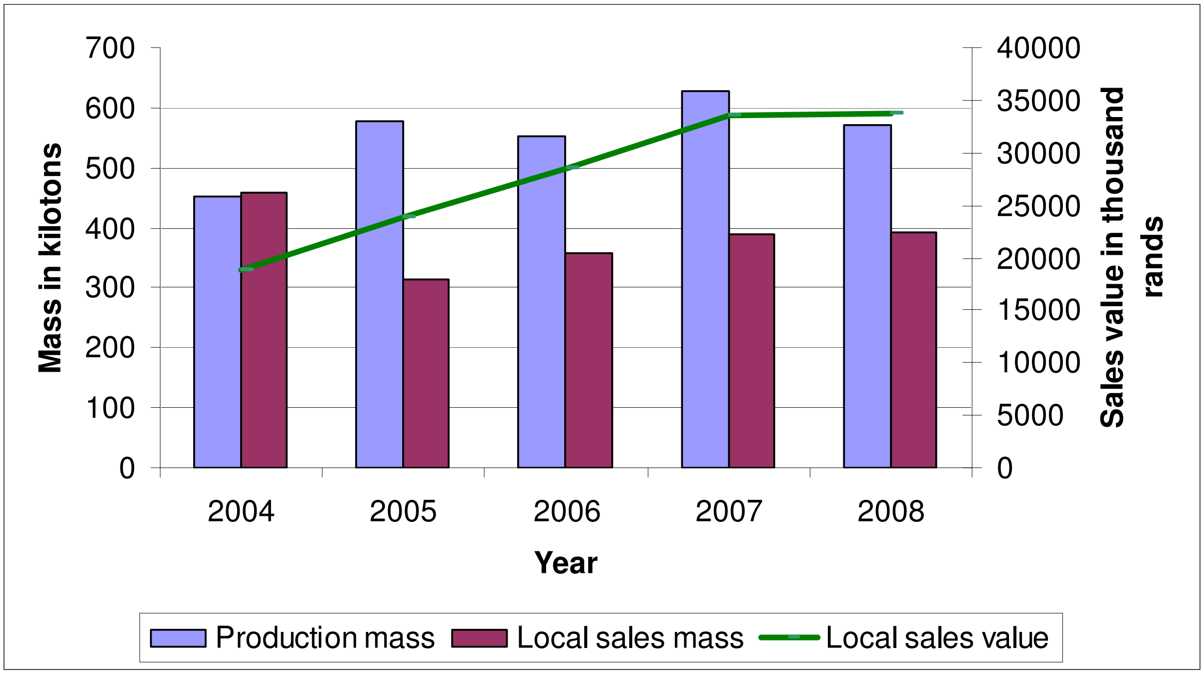


Source: Council for Geoscience, 2008.

3.2 PRODUCTION, SALES AND PRICES

South African gypsum production increased at an annualised growth rate of 6 percent from 2004 to 2008 (Fig. 5). The production and sales figures exclude synthetic gypsum, as these figures are not generally reported to the DME. More detail on this subject is given in the section dealing with synthetic gypsum. Local sales exhibited an annual growth rate of 15 percent, over the past five years. Owing to increased building activity, which has boosted demand for both cement and gypsum board.

FIGURE 5: LOCAL GYPSUM PRODUCTION AND SALES, 2004 – 2008

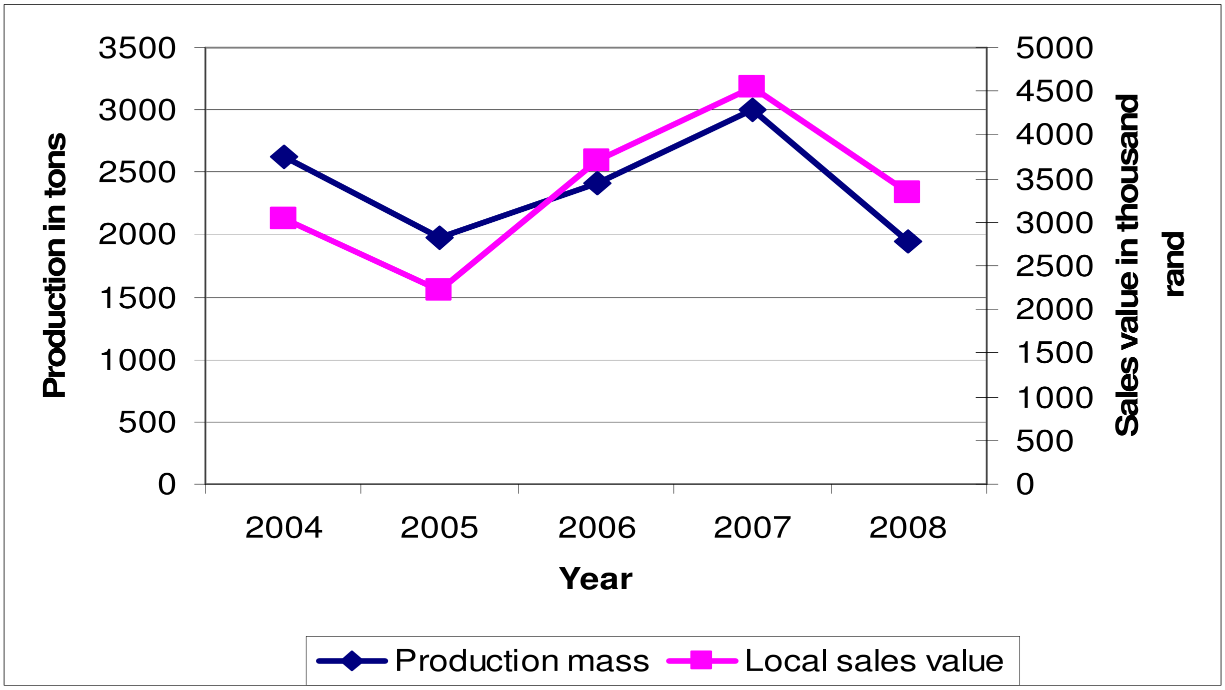


Source: DME, Directorate Mineral Economics.

3.3 IMPORTS

South Africa is a minor producer of natural gypsum but imports high quality material for specific niche markets. There has been a steady, marginal, decline in imports over the past 5 years, declining by 2 percent per annum as consumers switch back to locally produced material (Fig. 6). South African gypsum imports totalled 1.9 kt in 2008. The imports are of special quality for use in the food and pharmaceutical sectors. Gypsum used for human ingestion requires a minimum $CaSO_4$ content of 97% and a high degree of whiteness.

FIGURE 6: LOCAL IMPORTS OF GYPSUM, 2004 - 2008



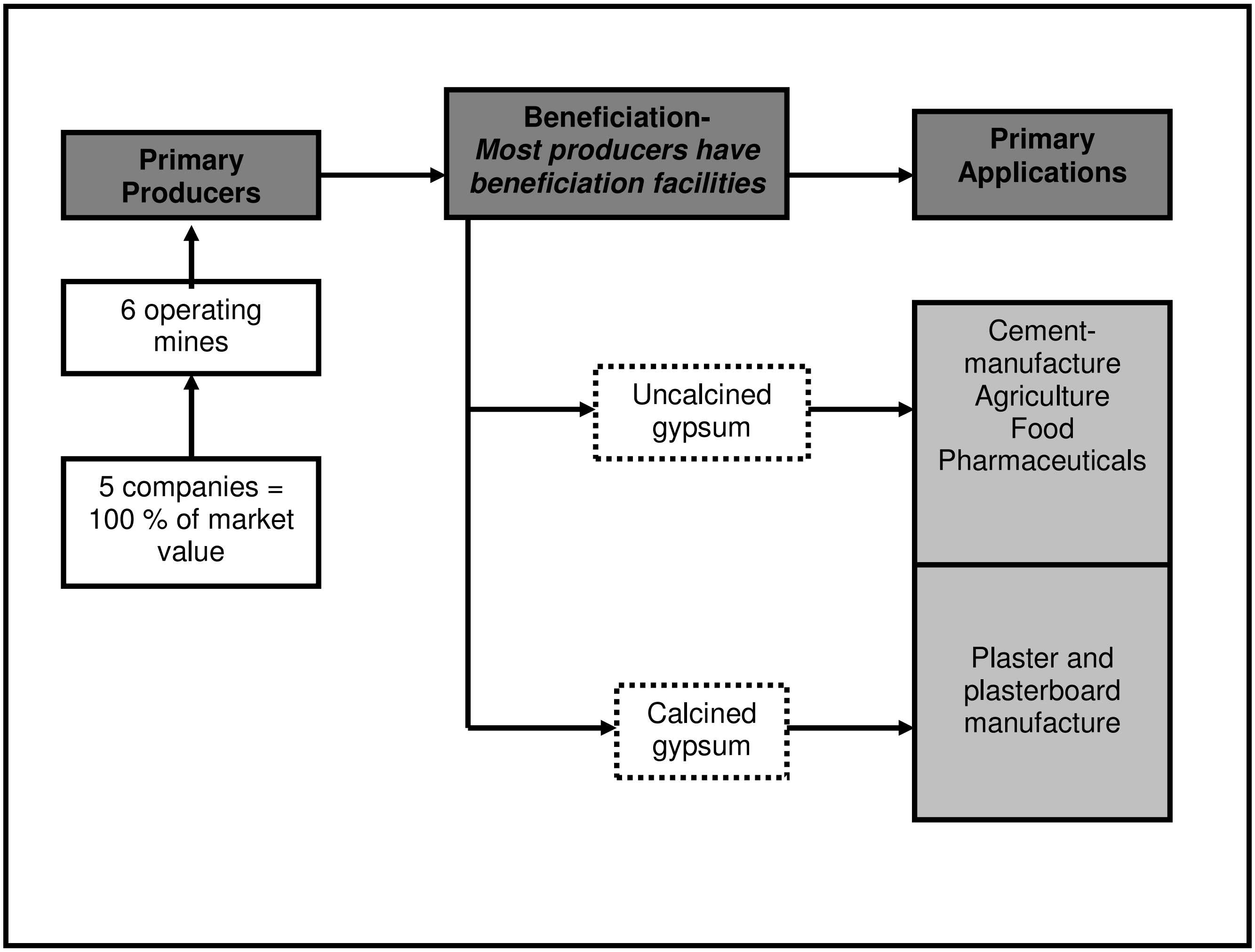
Source: DME, Directorate Mineral Economics.

3.4 END USES FOR NATURAL GYPSUM

The major use of calcined gypsum is in plasterboards. Other uses include joint filler, desiccant and mould making for pottery, sanitary ware and metal casting. Uncalcined gypsum is used in the manufacture of cement (3-6 percent added to clinker controls the setting time of cement), in soil treatment for agricultural purposes, as a filler in food and pharmaceuticals and as a flocculent.

Major markets for natural gypsum in South Africa are plasterboards and cement manufacture, followed by the agricultural sector where it is used for soil treatment.

FIGURE 7: SOUTH AFRICA'S GYPSUM INDUSTRY STRUCTURE



Source: DME, Mineral Economics

4. SYTHETIC GYPSUM

Synthetic gypsum is derived as a by-product from various industrial processes such as the manufacture of phosphoric acid, and titanium slag if the sulphate recovery process is used. In South Africa, nearly all the synthetic gypsum is produced as a by-product of phosphoric acid manufacture, with some being scrubbed from sulphide ore smelter stacks. All South African titanium slag producers use the chloride recovery method, with no gypsum by-product. Phosphogypsum (PG) and gypsum recovered by flue gas desulphurization (FGD) and fluidized bed coal combustion (FBC) could represent a useful resource.

FIGURE 8: SYNTHETIC GYPSUM

Gypsum Storage Site

FBC Spent Bed Gypsum material

FGD Gypsum material

Source: Centre for Applied Energy Research (United Kingdom), 2008

Industrial processes such as the production of phosphoric acid, titanium slag by the sulphate process, flue gas desulphurization (FGD) and fluidized bed coal combustion (FBC), yield different types of synthetic gypsum. In South Africa PG is the only significant synthetic gypsum produced. Smelters treating sulphide ores produce some FGD gypsum, but there is no information available on quantities.

In Europe, titanogypsum has over the years been produced as a by-product from the sulphate method of titanium slag production, and is an important supplement to natural gypsum. All titanium slag produced in South Africa is recovered using the chloride process, as this is the most effective process of treating South African ilmenite ($FeTiO_3$) ores.

Gypsum produced from coal-powered stations (FGD) has been viewed as a viable product in developed countries, where the implementation of clean-coal technologies is at an advanced stage. In South Africa other means of scrubbing power station flue gasses are used, and these produce sulphur, but not gypsum.

The FBC method of coal burning is being investigated in South Africa, but indications are that it will not be an economically feasible way of firing power stations at present. In the past synthetic gypsum has never been reported to the DME as a mined product, as a result of the wording of previous legislation. Foskor is the only mine producing rock phosphate concentrate, which provides the calcium radicle that goes into Phosphogypsum.

The sulphate component originates from sulphuric acid used in the process of phosphoric acid manufacture. Only in the case of Foskor does the same parent company mine apatite and produce PG. The PG is then discarded as waste into the sea. The MPRDA enables the DME to obtain returns from mineral processing plants, even though they are processing minerals that are mined by other companies. As PG is a potentially saleable product the production and sales should be reported to the DME.

4.1 PHOSPHOGYPSUM

Phosphogypsum is produced in large quantities during the manufacture of Phosphoric acid. Approximately 4,6t of gypsum is produced for every ton of phosphoric acid. The four local producers of phosphoric acid are: Sasol Nitro, Foskor Limited, Kynoch Fertilizer Pty Ltd and Omnia Pty Ltd, all produce PG.

The chemical reaction for phosphogypsum production is as follows:

$$Ca_{10}(PO_4)_6F_2 + 10\ H_2SO_4 \text{ -------- } 10\ CaSO_4 + 6\ H_3PO_4 + 2HF$$

Phosphate-rock	sufuric-acid	Phospho-gypsum	phosphoric-acid

The majority of Foskor's gypsum is pumped into the sea as waste, a common and accepted practice in the rest of the world. Sasol Nitro has a huge dump of gypsum at Phalaborwa. Other dumps are at Potchefstroom, Rustenburg (Phokeng), Modderfontein and Somerset West.

4.2 FLUE GAS DESULPHURIZATION GYPSUM

Gypsum produced through the process of flue gas desulfurization is known as Flue gas desulphurization Gypsum (FGD gypsum). An unknown quantity of FGD gypsum is scrubbed from the stacks of sulphide ore smelters. The product is impure as a result of the lack of filters prior to the sulphur scrubbing. If filters were to be installed the gypsum product could be of very good quality.

4.3 DISPOSAL OF PHOSPHOGYPSUM

Phosphogypsum is a controversial material and the subject of much research. The main reason for this is that it may pose a radiation threat, as all rock, phosphate contains a certain amount of radon and radio nuclide contamination. It has been proved that PG produced from igneous rocks, even carbonatites such as that hosting South Africa's major phosphate reserve at Phalaborwa, have lower radioactivity than sedimentary phosphate ores. Uranium has normally been enriched by seawater in all marine-deposited phosphates.

South African phosphogypsum is acceptable for general use, which was not necessarily the case in the past. It should be noted that imported phosphate rock concentrate, usually of sedimentary origin, when mixed with Foskor concentrate, might give rise to PG that may not meet the newly set radiation levels. As most other local purchasers of phosphate rock concentrate obtain it directly from Foskor Phalaborwa, it is unlikely to be contaminated by imported phosphate concentrate.

The disposal of phosphogypsum poses a serious problem, especially with large scale phosphoric acid production units of over 1000 tonne/day capacity which are recently being built. Around 5 tonnes of phosphogypsum are generated per ton of phosphoric acid expressed as P_2O_5 . This phosphogysum contains some of the trace elements from the phosphate rock, including cadmium and some radioactive elements.

Although it was previously a common practice for phosphoric plants situated on coats to pump gypsum into the sea, where it rapidly dissolves, recent restrictions on the disposal of phosphogypsum into sea water have been introduced, subject to restrictions on the cadmium content of the gypsum. The Department of Water Affairs and Forestry and the Department of Environmental Affairs and Tourism have applicable environmental legislation that has to be complied with for discharging of gypsum into water.

Three methods are available to deal with phosphogypsum, namely: use as saleable products, discharging into water and dumping on the land:

4.3.1 Use as saleable products

The use of phosphogypsum has been widely encouraged, but economic and quality problems and low demand for the resulting products frequently inhibit its use. These problems relate not only to the impurities in the phosphogypsum, but also to it's relatively moisture content. Plasterboard, plaster and cement are the main possibilities, but it is also possible to reuse phosphogypsum mainly in sulphuric acid production.

4.3.2 Discharging into water

The gypsum can be pumped trough an outlet into the sea at coastal sites. In other cases it is pumped into rivers, but this mode of disposal becomes economically less attractive if the receiving water is far away. Disposal of gypsum into the sea has the advantage that gypsum is more soluble in seawater than in fresh water. However, some of the impurities in the gypsum should be controlled. Gypsum itself is fully soluble and is not harmful to the environment. High efficiency (above 97 percent) of phosphoric acid production is essential for this method of disposal and good quality rock phosphate should be used in the plant, if the pollution is to be kept within environmental quality standards.

4.3.3 Dumping on the land.

Disposal on land is not possible everywhere because it requires space and certain soil quantities where the gypsum stack is situated. Belt conveyers to the gypsum storage pile transport dry gypsum from the plant. A ditch that collects run-off water, including any rainwater surrounds the pile area

4.4 CONDITION OF SOUTH AFRICAN PHOSPHOGYPSUM DUMPS

In order for synthetic gypsum to be of any use or value it should be clean. Many of the gypsum dumps at Phalaborwa have been used as sponges for other industrial waste, and also contaminated by windblown magnetite from the dumps/stockpiles.

Other dumps, particularly those at Rustenburg, Modderfontein and Potchefstroom, have been used as sponges for other waste materials. This could be a wasteful practice as the gypsum may be a usable resource; if not now, then in the future.

Gyproc has a large board plant in Japan that uses PG as its sole source of gypsum. This illustrates the potential value of a properly kept PG dump. In fact it is quite possible that some of the Japanese PG originates from Foskor Phalaborwa phosphate rock concentrate, as the company has been exporting to Japan.

4.5 USES FOR PHOSPHOGYPSUM

The possible uses of PG are dependent on various characteristics, mainly toxicity, whiteness and grain size.

- **Vitrification:** Glass and glass-ceramics can readily be made from PG and tailings sand. Possible products range from glass-ceramic floor, wall and roof tiles; synthetic wollastonite ($CaSiO_3$) fibres used in ceramics and paints and as a non-toxic substitute for asbestos; synthetic stone for building facades; abrasives; and container glass for selected beverages and agricultural products.

- **Wallboard:** Gypsum is the major constituent of commonly used wallboard. In South Africa the sources of gypsum are at considerable distances from the board factories. Mining costs constitute 15% of the cost of mining gypsum out of the ground and to the factories.

- **Road Bed:** PG can be used as a binder for base course mixtures, and has many advantages over clay mixtures used for this purpose.

- **Landfill Cover:** Bench and pilot scale testing indicates that PG used as a cover material speeds the degradation of waste materials and extends the useful life of landfills.

- **Oyster Culch**: Research is underway to find a PG/fly ash/cement mixture that is stable underwater, for use as oyster culch or artificial reefs.

- **Fillers and Coatings**: As a pigment, filler and extender gypsum must have a high degree of whiteness and purity in excess of 97-98% $CaSO_4$. Applications are in the plastics, paint, adhesives, food and pharmaceutical industries. PG may be developed for some of these purposes. As a filler and coating, PG is blended with kaolin to produce a low-abrasion, very white pigment, with good gloss, opacity and ink holdout characteristics. The solubility of the mineral may prove a problem in enclosed paper making systems.

5. ENVIRONMENTAL IMPACT

The primary environmental impacts of gypsum are habitat disruption from mining, associated emissions in processing and shipment, and solid waste from its disposal. Using synthetic gypsum or recycled gypsum board significantly reduces several of these impacts. However, raw gypsum is benign and is regularly consumed as a calcium supplement as well as in many foods, including wine, beer, cheeses, and bread.

There are potential emissions during gypsum processing, while particulate matter (PM) is the dominant pollutant in gypsum processing plants, several sources may emit gaseous pollutants also. The major sources of PM emissions include rotary dryers, grinding mills, calciners and board end sawing operations. Uncontrolled emissions from plaster mixing and bagging, conveying systems and storage bins are not well quantified. Gaseous emissions from gypsum processes result from fuel combustion and may include nitrogen oxides, sulphur oxides carbon monoxide and carbon dioxide.

Emission control devices are frequently needed to collect the product from some gypsum processes and, thus, are commonly thought of by industry as process equipment and not as added control devices. Emissions sources in gypsum plants are most often controlled with fabric filters. Some emissions from some gypsum sources are controlled with electrostatic precipitators (ESP)

6. CONCLUSION

South Africa has adequate, albeit fairly low grade, resources of natural gypsum, large resources of PG, although many dumps are contaminated with extraneous material, and there is a possibility of recovering high quality FGD gypsum.

The gypsum market is mainly dependent on the construction industry, which is linked to Gross Domestic Product and population growth. The current boom in the local construction industry, with huge demand for low cost housing in South Africa, and intended government spending on infrastructure. Also, with a growing population the demand from the agricultural sector should also increase.

The global financial crisis, which is showing signs of bottoming out, has affected construction activity and demand for gypsum products. The effect has been uneven, however, as emerging economies, particularly China and India have continued to expand, albeit at a slower pace, whilst mature economies e.g. the US have endured sales decline. The Local market for gypsum was boosted by government investment on infrastructure programmes.

Stimulus packages offered by governments to stabilize the world economy appear to be reviving demand for cement and plasterboard and demand growth is set to return to pre-recession rates. However, a renewed lower cost industry with a considerable shift to synthetic gypsum derived from environmental mitigation sources is beginning to emerge.

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