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REVIEW OF INDUSTRIAL MINERALS IN MOZAMBIQUE

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About 40 different industrial minerals (IM) are known to occur in Mozambique. However, at present their utilization for the production of basic construction materials as well as household and various industrial commodities is rather limited. In fact, the present situation is worse than it was in the 1960s and 1970s and this concerns the whole IM sector. In comparison with South Africa, the consumption of various industrial minerals in Mozambique is 10–20 times lower, and compared to industrialized countries the figures may be 100–200 times lower.

Taking into account the consequences of this situation it is quite clear that the basic infrastructure and housing facilities cannot be developed to a level that would markedly improve the living standards and conditions of the people. This also has a significant influence on the general socio-economic situation in the country. Without domestic production, most IM-based materials and goods have to be imported and this consumes a lot of foreign exchange.

In Mozambique there are many basic industrial mineral occurrences that meet the size and quality requirements for the production of the most important IM-based commodities. At present, economically the most important IM deposits in Mozambique are world-class heavy mineral sands at Moma (production started in 2007) and Corridor Sands at Chibuto (in the feasibility stage). Extensive coal deposits in Tete Province are also being thoroughly investigated, the most advanced investigation being the Moatize project (in the feasibility stage).

It is highly recommendable that the national authorities and companies involved in the IM sector seriously consider active measures to improve the prevailing, unsatisfactory situation that greatly affects the overall development of the country.

This review is based on the country-wide assessment of industrial minerals in Mozambique, carried out by the GTK Consortium in 2005–2007.

Key words (GeoRef Thesaurus AGI): economic geology, review, industrial minerals, construction materials, production, import, markets, Mozambique.

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INTRODUCTION

Mozambique has a large and diverse mineral resource potential. Despite this wealth, commercial mining and the overall utilization of mineral resources have played a relatively minor role in the development of the country's economy and social welfare, amounting to only 1.8% of GDP in 2006 (Yager 2007).

This review of industrial minerals (IM) in Mozambique will highlight the situation of the IM sector in general and in comparison with South Africa. General comments about the market are also made.

Industrial mineral raw materials and commodities made of these are essential for the economic development of any nation. The improvement of infrastructure and growth of the manufacturing sector requires a reliable supply of good quality construction materials based on a wide range of industrial minerals. Industrial minerals are also essential raw materials for various household and housing commodities in our every day life.

Unfortunately, in most developing countries the industrial mineral sector is poorly developed. Therefore, despite significant industrial mineral resources, developing countries continue to import these materials and ready-made products to supply their industries and directly the people. The threshold to utilize indigenous resources may be high because they have not been tested properly to prove that they meet the required industrial specifications and/or that the facilities and expertise to carry out the necessary evaluation and test work may not be available.

Unlike metallic minerals, the usability of industrial minerals generally depends more on physical than on chemical properties. A wide range of laboratory tests are needed to determine several inter-related properties that have to meet the requirements of consuming industries. Viable processing methods must also be studied.

However, once the above test work has been carried out successfully, the investments needed to set up the production of various industrial minerals are generally much lower than for metallic minerals. Of course, an entrepreneur with sound managerial and technical skills is required to run the business.

OVERVIEW OF IM COMMONDITIES IN MOZAMBIQUE

The map in Fig.1 presents over 350 deposits or occurrences of industrial minerals per se and of construction materials that are included in the Industrial Mineral Database of Mozambique. The work was carried out under the Mineral Resource Management Capacity Building Project within the Geochemical and Industrial Mineral Surveys (GIM) by the GTK Consortium in 2005–2007. A more detailed description of the activities and the results is presented in the Final Technical Report and Final Report: Results of the Industrial Mineral Survey of the GIM, which were delivered to the National Directorate of Geology in Mozambique at the end of the project.

Fig. 2 presents the high priority areas of IM commodities in the country. Table 1 summarises the statistics for the production of industrial minerals and construction materials in Mozambique and Table 2 the number of valid mining licences. In Table 3 the export and in Table 4 the import of IM commodities is presented.

Heavy mineral sands

Mozambique has several potential heavy mineral deposits along the 2500 km long coastline. Some of these are world class deposits in terms of grade and volume, such as the three most advanced projects which are briefly described in the following.

Moma

In April 2007 Kenmare Resources PLC from Ireland started the production of Ti and Zr minerals at their Moma property, in Nampula Province, and the first shipments were made in December 2007. According to the plan, 16.4 Mt ilmenite will be produced within the next 20 years, while the total reserves are 163 Mt (Mining Weekly, May 2007). The initial production of ilmenite concentrate was planned at 700 000 tonnes per year; however, in 2008, production is already expected to reach 800 000 tonnes of ilmenite, 56 000 tonnes of zircon and 21 000 tonnes of rutile (Industrial Minerals, December 2006).

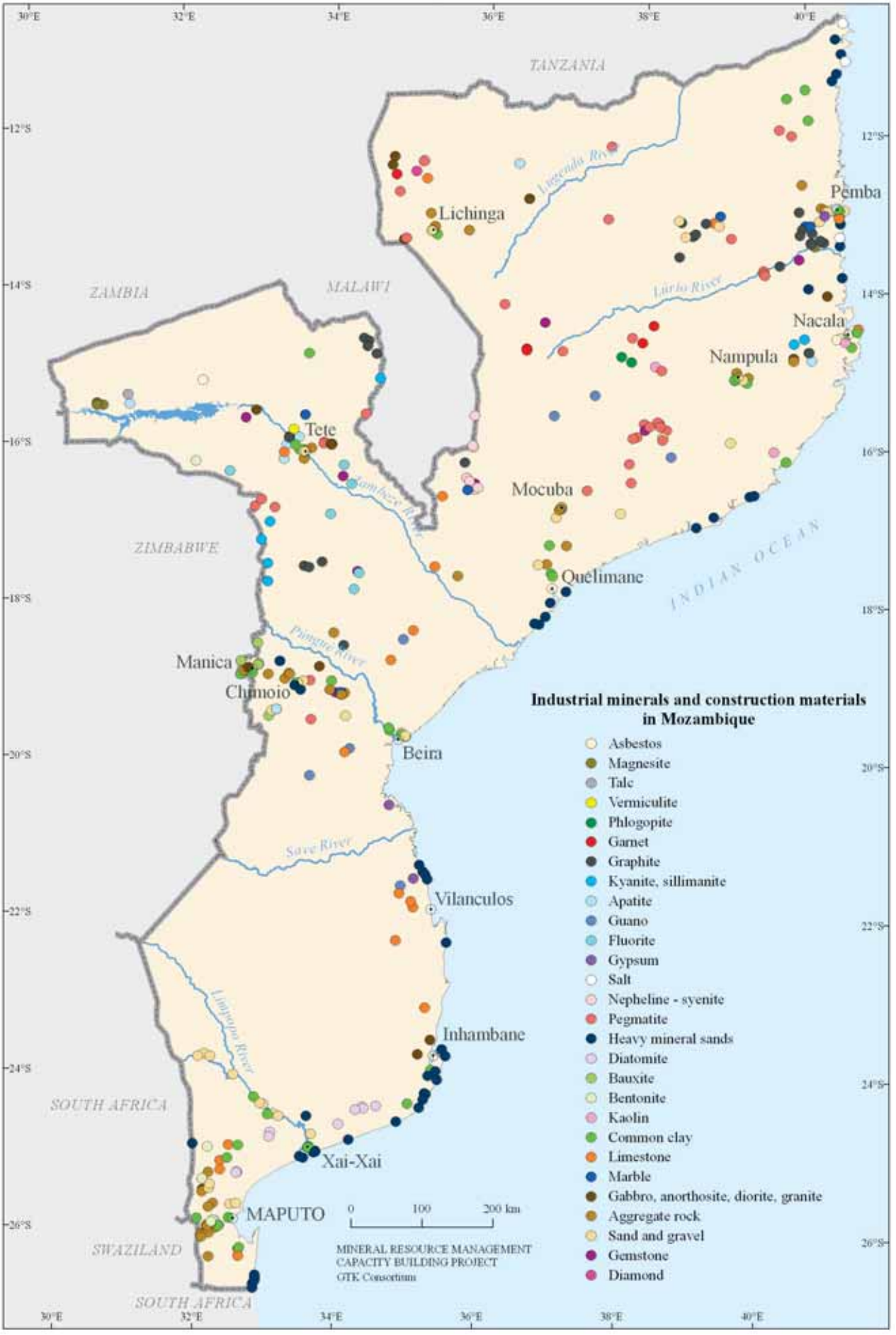

Fig. 1. Industrial minerals and construction materials in Mozambique.

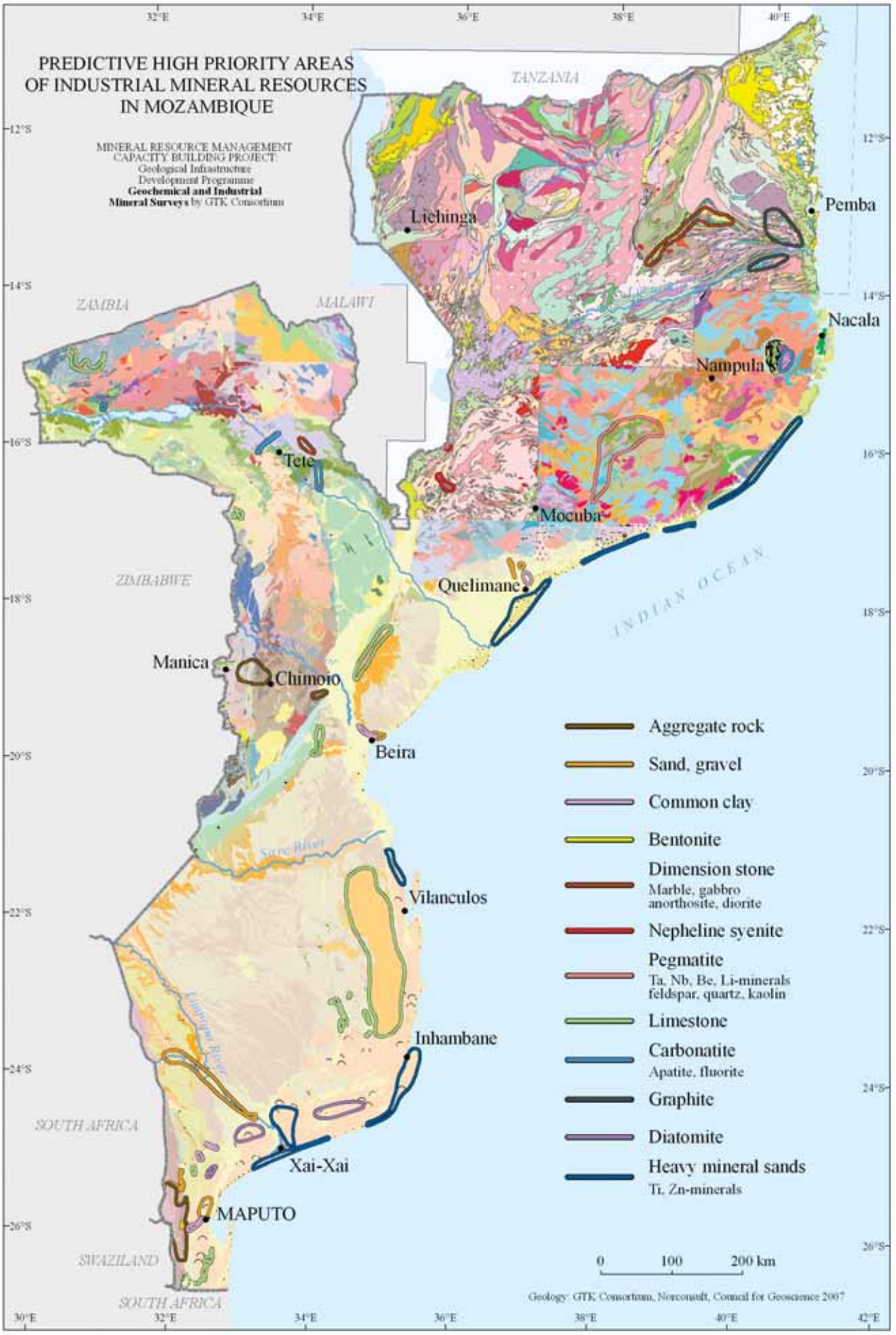

Fig. 2. The high priority areas of industrial mineral commodities in Mozambique. The geology of this map is based on the maps produced by the GTK Consortium, Nordconsult and the Council for Geoscience (South Africa) during the country-wide mapping programme in 2002–2007.

This project alone will greatly boost Mozambique's mineral industry. Total investments of the project will rise to over $400 m., including a 150-km powerline, concentration and roasting plants and a 450-m jetty for loading, as well as accommodation and social facilities for the employees. Altogether, the project is planned to create more than 400 permanent jobs when working to capacity.

Corridor Sands

BHP Billiton PLC's ilmenite project at Chibuto near Xai Xai in Gaza Province is at present at a standstill, because the costs have shot up since a feasibility study was completed in 2002 by WMC Resources, which BHP acquired in 2005.

However, BHP is fully committed to the project, and Corridor Sands "needs a new configuration to make it work" (BHP press release, February 2007). Under the revised plan, BHP will separate the mine from the smelter, which will be located close to Mozal aluminium plant, where BHP is a major shareholder. This would reduce the costs by US$300 million. The project will be developed further in three phases, the first one costing over $500 million, and the plant could be in production early next decade. With 100 Mt reserves of ilmenite, Corridor Sands will be a long-term asset of BHP's business strategy.

Rio Tinto Project

In addition to Kenmare and BHP Billiton, Rio Tinto PLC is also involved in exploring heavy mineral sands in Mozambique. They have carried out extensive drilling, sampling and testing programmes on several blocks along the coast between Inhambane and Xai Xai. However, Rio Tinto has not yet reached the stage of a feasibility study, which means that many years will pass before any decisions on production can be made. It should also be noted that Rio Tinto has a much further developed heavy mineral project in Madagascar, which naturally has a major effect on Rio Tinto's overall plans in the TiO_2 business.

Limestone and dolomite

Sedimentary limestones occur as extensive formations in the sedimentary sequence of coastal Mozambique (Lächelt 2004). The most prominent formations are the Salamanga (Fig. 3) to the south of Maputo and Cheringoma in two areas, along Buzi River to the west of Beira and on the Cheringoma plateau area to the north of Beira. Tertiary Salamanga limestones are exposed over a zone more than 10 km long and 1.5–2 km wide. The average thickness is 32 m. The second large accumulation is the Miocene Jofane Formation, extending from south of Save River to Inhambane. All these deposits have large reserves of limestone that meet the quality requirements for cement, agriculture and other purposes. At present major production is only taking place at Salamanga for CIMOC's Matola cement plant. In addition, minor amounts of coral limestone from Relanzapo area near Nacala are mixed into imported clinker for cement production in the Nacala plants of CIMOC and ARJ Group. The third cement plant of CIMOC, close to Beira in Dondo, acquires limestone from Muanza quarry (Cheringoma Formation), about 100 km north of the plant, mixing it with imported clinker in cement manufacture.

Crystalline limestones (marbles) are present in almost all Archean – Precambrian complexes in Mozambique. Previously, several of these were used for lime production; one was near Manica, another in Boroma, near Tete, and the third at Malula near Lichinga. Some other carbonate rock deposits have also been utilized for lime. However, at present there is no production in the country and the lime needed for the sugar and other industries is imported.

Cement production from domestic raw materials is currently also being reduced. At the moment, three cement plants (Dondo, near Beira and two in Nacala) use imported clinker, and in the Matola plant, decreasing amounts of Salamanga limestone are also being used and more clinker is being imported (Tables 1 and 4).

At Montepuez in Cabo Delgado (Fig. 2), a large marble deposit is quarried for dimension stone (slabs, plates, blocks). The deposit is mainly dolomite in composition and in certain layers the dolomite is very pure in chemical composition (see: GTK Consortium 2007b, Results of the Industrial Mineral Survey).

Fig. 3. Salamanga limestone quarry, Bela Vista.

Table 1. Industrial mineral (IM) production during 1996 – 2006.

COMMODITY	Unit	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Bauxite	t	11 460	8 218	6 132	7 883	8 130	9 592	9 119	11 793	8 977	9 518	11 069
Bentonite	t	11 847	13 782	11 133	11 187	29 987	21 865	16 174	25 311	20 571	17 865	4 207
Beryl	t					18.8	0.8	54.0	78.3	27.3	146.3	16.4
Carbonate rock	t					585 590	729 230	1 301 232	1 348 372	1 593 449	654 179	155 870
Graphite	t	3 283	5 125	5 889	4 006							
Quartz	t						24.7	31.3	31.0	173.5	294.7	195.1
Tantalite	t					25.000	27.000	46.900	188.700	712.100	88.025	51.153
Marble	m2	9 881	13 820	2 736	16 296	14 640	15 303	9 980	10 227	13 666	12 153	12 825
Marble	m3	744	251	117	117	453	320	453	320	617	509	472
"Granite"	m3					795.0	661.5	669.7	539.0	520.8	2 198.0	
Dumortierite	t					60.0	50.0	40.0	40.0	113.0	10.0	664.0
Garnet	t										5.80	10.33
Clay	t							84 024	100 176	108 231	32 030	222 052
Sand	t					299 540	464 684	795 813	1 372 032	1 429 742	833 113	1 404 184
Aggregate	m3			283 000	265 000	592 358	490 737	795 732	742 501	779 581	850 918	1 178 997

Source: Ministry of Mineral Resources, Mozambique.

Diatomite

Diatomite (*Kieselguhr*) has accumulated in many fluvial and lagoonal depressions between Pleistocene dunes from Inhambane in the north to Matutuine, south of Maputo. The diatomite was deposited in rivers, small lakes and ponds under brackish to freshwater conditions. The deposits are usually small with a maximum thickness of 1.5–2.5 m. The Boane and Manhiça occurrences are best known.

Fig. 4. Diana diatomite quarry, Manhiça area.

The Manhiça diatomite deposit is located about 10 km southwest of Manhiça town and the main pit, Diana, is now in production after a long standstill (Fig. 4). The horizontal diatomite layer measures 0.45 km x 3.6 km and is about 4–5 m thick with an average overburden of 1 m. The estimated reserves are 1.5 Mt and the pure diatomite content is 50% (Afonso and Marques 1993). Additional deposits at Alvor and Marina in the same zone have estimated reserves of 0.96 Mt and 1.5 Mt. The Manhiça diatomite layers are distributed over a surface area of 1 100 km² (Cilek 1989). Diatomite is dried, milled, screened and split into various qualities and exported mainly to customers in South Africa.

However, the diatomite production does not appear in the statistics of the Ministry of Mineral Resources (Table 1). In 2006 the production was 100–120 tonnes per month, making over 1000 tpa (pers. comm. C. Braz, Diatomites de Mozambique). At present the local consumption is only minimal, and the real added value for these products is made abroad. Instead of utilizing this well studied and tested domestic resource, commercial diatomite products are imported into Mozambique.

There are also other diatomite occurrences between Magude and Chokwe at Maduaine and around the Mafuiane and Buoana, in Gaza Province.

Aggregate rocks

Karoo rhyolites provide a good raw material for aggregate. The majority of active stone quarries are located around Maputo, where the economic activity is highest. Stone quarries are concentrated in the districts of Namaacha, Boane, Matutuine and Moamba. The raw materials in southern Mozambique serve the development corridors along the National Road EN1, Maputo Corridor (Maputo-Ressano Garçia), National Road EN2 (Maputo-Namaacha), Lebombo Corridor (Boane-South African border) and also the Limpopo-Chibuto Development Zone.

The quarried aggregate rocks are mostly rhyolites of the Lebombos Range. Rhyolite is more resistant against weathering than andesite and basalt from the

same range and is a good material for most road and other construction purposes. In the Moamba district, a good quality, fine- to medium-grained nepheline syenite is also quarried for aggregate by CMC, which with the other big construction companies Tamega, Extramac, Riolitos, Probrita, ARA Sul and MAM are all active in the Namaacha-Boane belt.

Most of the geological construction materials are used for roads and buildings, and accordingly the field verification of this study is focused on the area where the economic activity is greatest, i.e. around the city of Maputo. This is also seen in the number of valid mining licences (mining concessions and mining certificates) in Table 2.

The aggregate from the quarries of this area is transported and used along the coast as far as Gaza and Inhambane (EN1), where suitable aggregate rock is not found due to geological reasons. Occasionally, aggregate for road rehabilitation has been transported as far as to the Save River. Road transport of bulk aggregate over hundreds of kilometres is expensive. Sea transport by barges would offer a much cheaper alternative, whenever possible.

In Gaza Province, rhyolite is quarried inland at Massingir. Large rhyolite blocks are transported 28 km to the Massingir dam construction site, where the blocks are used for the earth wall of an irrigation dam across dos Elefantes River.

Granodioritic domes along the Beira Corridor are quarried in several locations for road and railway rehabilitation. The closest exposed hard rocks to the coast and Beira are felsic to mafic volcanics at

Table 2. Number of valid mining licences for aggregate rock, sand & gravel and brick clay, Mining Cadastre, 2005.

PROVINCE	STONE	SAND &GRAVEL	CLAY	TOTAL
Cabo Delgado	1	3	-	4
Gaza	2	5	-	7
Inhambane	3	1	-	4
Manica	7	3	1	11
Maputo	17	37	5	59
Nampula	3	1	-	4
Niassa	-	-	-	0
Sofala	3	2	-	5
Tete	2	6	-	8
Zambezia	13	2	-	15
	51	60	6	117

Source: Department of Mines, Ministry of Mineral Resources, Mozambique.

Table 3. Export of IM commodities in Mozambique during 2003-2006.

COMMODITY	Unit	2003	2004	2005	2006
Bauxite	t	11739	6 723	6 610	2 766
Bentonite	t	24694	13 026	12 938	3 111
Beryl	t	21	0.9	2 369.0	0.3
Quartz	t			0.0	72.4
Diatomite	t				367.5
Tantalite	t	168.5	367.5	88.0	51.0
Marble	m2	804	1 970	0	2 006
Marble	m3				
"Granite"	m3	330.4	2 787.0	0.0	20.0
Dumortierite	t	20.1	42.0	10.0	0
Garnet	t	0.72	6.89	2.15	0.23

Source: Customs Department of Mozambique.

Table 4. Import of industrial minerals and commodities in 2005 and 2006.

Commodity	Gross weight in tonnes 2006	Gross weight in tonnes 2005	Country of origin	Value in MMTn in 2006	Value in MMTn in 2005
Aggregates	67	123	SA	0,5	0,55
Dimension stone	203	48	SA	2,6	1,8
Salt	80	100	SA, Portugal, others	7,5	1,3
Asbestos	669	669	ZIM, SA	9,6	7,7
Silica sand	220	141	SA, India, Belgium, others	2,6	1,9
Other sands	223	212	SA, India	1,3	0,95
Kaolin	107	26	SA	1,9	2,2
Bentonite	23	9	SA, Portugal	0,6	0,14
Other clays	153	133	India, SA	2,6	1,7
Andalusite,kyanite	167	na	China, India	5,6	na
Chalk	242	48	SA, Tanzania, ZIM	2,3	0,16
Gypsum	7 100	8374	SA, Tanzania, ZIM	49,6	18.6 ?
Gibbsite, anhydrite	68	17,5	SA	0.1 ?	0.23 ?
Natural Ca-phosphates	70	19,8	SA, ZIM	0,5	0,4
Diatomite	61	35	SA	2,6	1,1
Dolomite products	89	88,5	SA	0,4	0,3
Quick lime	479	1117	SA	5,3	7,3
Slaked lime	1 850	94	SA	64,6	0,9
Hydraulic lime	1 300	1084	SA	7,8	6,4
Clinker or Portland cement	221 kt	116 kt	Several countries	779,9	459
White cement	275 kt	10.1 kt	SA,India	21	15.2 ?
Other cements	100.6 kt	80 kt	SA, ZIM	125	163
Nitric fertilizers	17 000	na	SA, Switzerland, others	279,8	na
Phosphatic fertilizers	218	na	SA	4,2	na
Potassic fertilizers	17	na	SA	2,8	na
Fert., Cont. 2–3 of N/P/K	17 300	na	SA, Switzerland, others	769	na

Source: Customs Department of Mozambique.

Xiluvo, where carbonatite rock is also quarried for upgrading of the national railway lines. Three quarries are currently in operation in the Xiluvo area. The Nharuchonga quarry, located some 120 km by road from Beira, produces aggregate, mainly from felsic volcanics.

About 100 km north of Inchope, on the western slope of Gorongosa Mountain, hard and dense charnockitic rock makes excellent aggregate and also the location is good. In the Chimoio – Manica area there are a few inselbergs of gneissose granitoids with good material for various aggregates whenever the demand arises.

In Tete Province there is one aggregate rock quarry in operation (CETA Lda) in Moatize. This exploits anorthosite-gabbro of the Tete Suite. Another, currently dormant, quarry in Chacocoma granitoid-gabbro is located 20 km south of Tete town by the main road.

Crystalline granitic rocks, suitable for aggregates, are common in central and northern parts of Zambézia as well as in most parts of Nampula, Cabo Delgado and Niassa Provinces. However, only a few quarries are in operation in Zambézia and Nampula, where the demand for road and house construction is currently active. Small artisanal pits supply the need in areas without major construction activities. In coastal areas where hard crystalline rocks do not occur, fossiliferous limestone materials are commonly used for construction and much is produced by artisanals (Fig. 5).

Fig. 5. Artisanal sale of limestone aggregate near Massinga, Inhambane.

Sand and gravel

In the Maputo area the availability of sand and gravel is not as good as that of rock aggregates. Most of the extraction sites contain fine-grained flood plain sand along the Umbeluzi River (Boane area) and Incomati River (Moamba area). The sand from these locations is best suited to mortar applications and fillings. Fine dune sand is also excavated for these purposes. Satisfactory gravel was only found upstream in the Umbeluzi River, near the town of Goba. Rather coarse and well-graded sand is also excavated at one site from the bottom of the Incomati River close to Moamba. North of Moamba towards Magude, gravel is found along the banks of the Incomati River at several sites in Gaza province. The pebbles are in general of limestone or calcarenite, indicating that such gravel does not fulfil the requirements of good, hard rock aggregate.

In the southern part of the Gaza province, sand and gravel deposits occur along the Limpopo and dos Elefantes Rivers.

In most parts of Central and Northern Provinces, Manica, Tete, Zambezia, Nampula, Cabo Delgado and Niassa, sand and gravel are, in addition to hard rock aggregates, adequately available within a reasonable distance from the main development centres and sites of major demand.

Table 2 shows that the activities (number of valid licences) involving construction materials were rather small in northern territories in 2005, which clearly indicates that major construction projects were not ongoing. However, the situation has substantially changed since then owing to major construction works of roads, railways, and projects such as Moma ilmenite and Moatize coal. These, together with the high general growth of economy, will all contribute to the greatly increasing demand for all kinds of construction materials in Mozambique.

Clays

Bauxite

Bauxite occurs in a lateritic weathering profile at Moriangane near Manica just on the border with Zimbabwe (Fig. 6). The deposit comprises several small, only 1m thick bodies of bauxite and gibbsite that are overlain by kaolinitic clay (Cilek 1989). Mining has been on going since the late 1930s and in recent years the production has totalled about 10 000 tonnes per year. This has been exported to

Zimbabwe and mainly used as a raw material for aluminium sulphate. Bauxite reserves have been estimated at 10 Mt and those of white kaolinitic clays are assumed to be from 10 to 15 Mt.

Bentonite

Bentonite occurs as a weathering product of rhyolites and rhyolitic tuffs of the Karoo volcanics in the Libombos Pequenos range of the Boane area, in the southwest.

The proven and probable reserves have been estimated at 6.5 Mt. The quality of montmorillonitic Ca bentonite is hampered by a high content of cristobalite (Cilek 1989) or opaline silica (Presley 1991). The production was been about 20 000 tonnes per year from 2000–2005 and it is exported mainly as bulk to South Africa and Zimbabwe. Only a few hundred tonnes have been Na-treated annually at site.

Kaolin

Various types of kaolin occurrences are common in Mozambique. Hydrothermal types are only of theoretical interest and known sedimentary deposits are of low grade. However, several weathering-type deposits are known from pegmatite bodies, especially in the Alto Ligonha district in Zambezia and Nampula Provinces. Only at Ribaue pegmatite mine has kaolin previously been produced as a by-product, but today this occurs nowhere.

It is known and reasonably well studied that a few other pegmatites (Muiane, Marropino, Nuaparra, Boila) also have a rather thick kaolinitic weathering crust (Fig. 7). Considering the available test results of various kaolins, it looks obvious that at least some of these could easily be processed to meet the properties required for different industrial uses: for instance, co-processing of kaolin as a by-product in pegmatite (tantalite) mining. The results of Muiane kaolin tests as part of the Industrial Mineral Survey have been published in a report (GTK Consortium 2007b).

Other clays

Other clays of differing quality are known in most parts of the country where the demand has existed. The deposits consist of plastic, kaolinitic and common types, but until now serious studies on their quality, usability and amount have only occasionally been carried out (Lächelt 2004).

Fig. 6. Moriangane bauxite mine, Manica.

Fig. 7. Kaolin weathering in Muiane pegmatite.

At present, even the production of normal bricks for construction is at a standstill in many districts where industrial scale factories previously operated. Ceramic tiles and similar goods are all presently imported.

Without sufficient industrial production of common bricks for construction, most of these are made by local people (Figs 8 and 9). This takes place around the large country, often utilizing unsatisfactory raw materials and consuming huge amounts firewood for very inefficient burning of bricks. This is contributing to the devastation of forests and before long other environmental problems will also appear (e.g. increased flooding).

Fig. 8. Artisanal brick production in Magude, Maputo.

Fig. 9. Ceramica de Vila Pery brick factory, Chimoio.

Tantalite

The potential of pegmatite minerals, especially tantalite, is known to be good in Mozambique and the area with the best potential is Alto Ligonha in Zambezia and Nampula Provinces (Afonso & Marques 1993).

At present, the *Marropino deposit* is the only one where tantalite is exploited on an industrial scale (Fig. 10). The operator is Highland African Mining Company (HAMC), and they plan to establish a new processing plant to improve the recovery of tantalite and increase the capacity. The deposit itself consists of strongly weathered (kaolinized) pegmatite, containing various bodies, the main one being over 550 m long and 250 m wide. Hard quartz veins occur occasionally. The reserves have been estimated at 10 Mt with a tantalite content below 300 g/t. With the planned capacity, the reserves to be mined will be exhausted in seven years. In addition to tantalite, the deposit contains small amounts of morganite and other semi-precious stones, and at present there are plans to also recover these in processing.

The *Muiane deposit* is also a strongly kaolinized pegmatite body (1200 m x 100m), which was already mined in colonial times (Cilek 1989). After a break of several years in operation, Metallurgical Design and Management (MDM) of SA is currently setting up a new processing plant. As in Marropino, the tantalite grade in Muiane is also less than 300 g/t.

At the *Naquissupa deposit*, Hegemony Resources set up a processing plant with an installed capacity of 120 t/h. The construction was completed in November 2001 when production was to be started. However, no tantalite ever came for sale. Surprisingly, the plant was planned for soft rock (kaolinized) material, but the deposit mainly consists of hard rock. At present, the unused processing plant and other machinery are rusting in Naquissupa.

In Mozambique the *Morrua pegmatite deposit*, close to Marropino, has obviously the best potential of the tantalite resources. It covers about 0.6 km^2 and is mineable to a depth of 100 m. The deposit has a long and colourful history starting from colonial times, but at present everything is at a standstill. Only 100–200 artisanal miners are panning tantalite in nearby Melela River. The deposit is a hard rock pegmatite body with developed zoning. The reserves are estimated at 3.5 Mt in hard rock and about 1.5 Mt in eluvium and re-processable "waste". The tantalite grade in hard rock is estimated at 700 g/t Ta_2O_5. In 2003 the company KHA set up a pilot plant with a capacity of 30 t/h to process the existing waste, estimated to contain 200–300 g/t Ta_2O_5.

However, at present the ownership of the mineral rights to the Morrua deposit are in the hands of the HAMC, which also operates in Marropino, and has plans to carry on its development. The African Ea-

Fig. 10. The tantalite plant at Marropino.

gle company is investigating its tantalite properties in the Namama Belt. Several other companies (Alvorada de Mocambique Lda, Australian Longreach Gold Oil Ltd and others) have also had or are holding tantalite mining and exploration licenses in the country.

Besides tantalite, the pegmatites in the Proterozoic rocks in Alto Ligonha also have a good potential for Nb and Li minerals as well as beryl, tourmaline and quartz, which occasionally occur even as gem quality varieties. In addition, the pegmatites contain feldspar and kaolin, which were previously also mined, and there is still the potential to re-start these activities.

Semi-precious stones

Pegmatites in Zambezia, Nampula and Tete Provinces are the most common host rocks of gemstone-quality minerals such as beryl, tourmaline, quartz and feldspar (Afonso and Marques, 1993, Lächelt, 2004). The pegmatites in the Alto Ligonha area, Zambezia, are particularly known and may have potential in the future (Bettencourt Dias & Wilson, 2000). Skarns, biotite schists and gneisses may host garnet, corundum, dumortierite and Karoo basalts may be agate-bearing. Most gemstones have been produced by artisanal small scale miners, who generally work periodically and often in the areas where pegmatites have been exploited on an industrial scale, mostly for tantalite. Owing to the periodic work of artisanals, the production figures of gemstones are unreliable and they also vary to a great extent annually (Table 1).

Some indications of diamonds have also been found in Mozambique, such as a few micro-diamonds recovered in Gaza Province, which are assumed to be derived from the alluvial sources of rivers draining from South Africa and Zimbabwe (Limpopo and Singédzi). Although close to 50 kimberlite pipes and dykes have been found in the Province of Niassa, to the north of the town of Lichinga, only a little work has been carried out to evaluate their diamond potential.

Salt

Mozambique is producing marine salt from evaporation ponds, which can sometimes be damaged by flooding, causing the salt industry to shut down temporarily. The salt is exported to Lesotho, Malawi, Swaziland and Zimbabwe. There are plans to raise funds for the rehabilitation and long term development of the industry through the UN Industrial Development Organization (UNIDO).

Dimension stone

Marble is the only dimension stone that is permanently produced for sale in Mozambique (Fig. 11). *Marmonte in Montepuez* (Cabo Delgado) quarries white, grey and multicoloured marble blocks for processing in their facilities in the town of Pemba. A part of the production is exported (Table 1 and 3).

The "granites" in Table 1 are granites and anorthosites quarried in Tete Province. The quarries are at present mainly used for extracting blocks for material tests and market surveys, but not for permanent commercial exploitation. The licence holders are Marlin Granite from South Africa and Clover from Zimbabwe.

Massive 'black granite' (actually gabbro) is periodically quarried for export at Chainça near Manica, like anorthosite from the Tete Suite and porphyric granite from the Songo area. Some other sites have also occasionally been exploited for dimension stone, but only on a small scale. Especially the de-

Fig. 11. Montepuez marble quarry, Cabo Delgado.

mand for Tete anorthosite/gabbro seems to greatly fluctuate, which obviously depends on the trends in the world market, for which these blocks are mainly aimed. Transportation by trucks to Beira port is currently also very costly.

Karoo rhyolites outcropping in the south-west have also occasionally been quarried for dimension stone, in Boane, Estevel and near Ressano Graçia. The banding and folding of light brown rhyolites may be very ornamental. However, the block size in the fractured, dense rock is problematic.

Graphite

The graphite mine and dressing plant of *Grafites de Ancuabe*, 100 km inland from the port of Pemba, in Cabo Delgado Province, is owned by Kenmare Resources (84%) and the government of Mozambique (16%). The mine was in operation in 1994–1999 and it had a capacity of 10 000 tpa of high grade flake graphite concentrate (more than 98% carbon). Development of the mine was based on 24 Mt of ore reserves with 3 to 11% graphite, identified during the pre-1995 exploration. At present it is under care and maintenance. The high energy costs (diesel generated) and tightened price competition in the world market were major reasons for the standstill.

In addition to several other occurrences in Cabo Delgado, graphite occurs in Angónia, Tete Province, in biotite-amphibole gneisses, granulites and anorthosites (Cilek 1989, Lächelt 2004).

Phosphates

Norsk Hydro from Norway investigated Mozambique's largest phosphate deposit at Evate in the late 1990s. The Evate apatite-bearing carbonatite deposit is located within the Monapo Klippe (structure) in the Nampula Province. Norsk Hydro has defined the ore resource and initially estimated the exploitable ore in the regolith zone at 43 Mt 6.2% P_2O_5. Unfortunately, no reports on the processing and quality of the apatite concentrate were available for this study. Almost four hundred drill holes were sunk and many of them also reached the fresh carbonatite. However, neither the results of processing tests, nor samples were found in the archives. A set of samples was collected from regolith material (Fig. 12) and from small outcrops of fresh rock for testing, and the results are given in Final Result Report of the GTK Consortium.

Besides Evate, other carbonatite bodies occur in Tete Province, of which Mt Muande and Mt Fema have potential for phosphates. Carbonatite pipes, Cone Negose and Mt Muambe have only marginal potential.

Mt. Muande carbonatite, about 30 km NW of Tete, was rather well investigated by a Yugoslav team in the 1980s. A that time the main interest was in the magnetite content of the deposit and apatite was only considered as a possible by-product (Brodoimpecks 1984). According to the report by the Yugoslav team, apatite was difficult to concentrate. A set of samples of un-weathered, apatite-rich carbonatite was collected for processing tests by this project. The results are presented in GTK Consortium (2007b), Results of the Industrial Mineral Survey.

Guano deposits (from bats) occur in caves and caverns formed mostly in Tertiary limestones. The best known guano caves occur in the areas of Vilankulo, Buzi and Cheringoma. Previously (before 1980), guano was actively exploited to supply local demand, but at present the production is very small.

Fig. 12. Sampling in Evate regolith zone.

MARKET SITUATION AND RECOMMENDATIONS

When considering the data presented in Tables 1–4, a few observations may be concluded. Firstly, it is fully clear that the Industrial Minerals sector at large is poorly developed in Mozambique and far from satisfactory in order to be able to support the balanced growth of the national economy and contribute to the general welfare of the population.

When looking at certain figures of the production data it is easy to understand why the overall infrastructure of Mozambique is poorly developed. The production of basic construction materials such as sand, gravel and aggregates is on an annual level of about 2–3 Mt, which makes ca. 100–150 kg/capita. The respective figures in South Africa (source: South Africa's Mineral Industry 2005/2006, Department of Minerals and Energy) are 50 Mtpa of production, making about 1.0 t/capita and in Finland 100 Mtpa and 20t/capita per year (source: Geological Survey of Finland). This means that for construction and maintenance of the infrastructure and housing, South Africa consumes 10 and Finland 200 times more aggregates and sand per capita than Mozambique (it is to be noted that in Finland the severe winter with frost has a considerable influence on construction requirements). This same trend is also seen in the annual consumption of cement, which is below 50 kg/capita in Mozambique, 250 kg/capita in South Africa and 350 kg/capita in Finland (Ministry of Trade and Industry). Similarly, the consumption of clays is 10 kg/capita in Mozambique as compared with 210 kg/capita in South Africa. However, it has to be stated that the statistics available from Mozambique are lacking the large amounts of materials produced by artisanal people, who are very much involved in making bricks, digging sand and even quarrying hard rock aggregates. Nevertheless, the above figures indicate that the production of basic construction materials is clearly inadequate to contribute efficiently to the overall development of infrastructure and housing facilities.

It is recommended that the authorities and companies involved seriously consider the measures needed to improve the situation. In South Africa it is understood that the maintenance and improvement of infrastructure, especially low-cost housing, ports, railways and roads is the key to the sustained growth of construction industries and also employment. Unfortunately, most statistics on the production, export and import of IM commodities in Mozambique are either not available or are not sufficiently reliable to allow detailed comparison with other commodities between these countries.

However, looking at overall figures for IM production, export and import in South Africa in relation to Mozambique, some concluding remarks can be made. In this inspection, those minerals/commodities that do occur in Mozambique are emphasized.

At first it is worth noting that the total IM sales in South Africa in 2005 were worth R6.9 billion (USD 1 130 million, source: South Africa's Mineral Industry 2005/2006, Department of Minerals and Energy). Ilmenite production in South Africa in 2005 totalled 950 kt, with a value of $95 million and $100 per tonne, as slag value added worth $500 per tonne and as TiO_2 pigment worth $2500 per tonne. Ilmenite production at Moma is estimated to reach 700 ktpa in the first year, which alone will increase Mozambique's mineral sector revenue substantially.

At present, limestone and the products based on it are the most valuable IM commodities in Mozambique. In South Africa the production of limestone amounts to about 15 Mtpa, with a value of about R 50 million. In Mozambique the local production of limestone has decreased from 1 Mtpa to 0.6 Mtpa and at the same time its import is increasing, being 0.32 Mt in 2006. In addition, less local limestone and more imported clinker is being used for cement manufacture. In 2006 the value of cement and clinker imports was MT 925 million. Although the Mozambique economy is essentially dependent on agriculture, hardly any agricultural limestone is used in acid soil regulation. Possible exceptions are a few commercial farms that use imported fertilizers and lime.

In addition to limestone, various lime products are imported, costing MT 80 million. This is one area that should be seriously considered by the authorities and companies in charge of the production and consumption of limestone-based commodities. It is clear that almost all foreign exchange used for importing the limestone based products could be saved by exploiting domestic raw materials, because deposits that meet the quality and size requirements occur adequately in the country.

Clays in general are another sector that could and should drastically be developed. In previous times, industrial scale brick factories operated in all districts, but today only a few are active and hardly any with satisfactory machinery. The clay material used is also poorly tested, causing considerable losses when firing the bricks. At present, most bricks used for building houses around the country are locally made by artisanal workers, often using inferior materials and burning bricks by consuming a lot of

firewood and thereby contributing to the devastation of valuable forests.

When looking at the import figures for IM commodities there are a few minerals that could be produced, have been produced and/or are currently produced in Mozambique. One is diatomite, of which about 1000 tpa is produced. However, the production is all exported because local consumers use imported diatomite, even though the local products meet the quality requirements. Various sand products are also imported, although the country has endless resources of sand to be processed for various industrial uses. Even glass production could be restarted.

There are some minerals in Mozambique which could be exploited and processed to make various fillers, pigments, extenders and so on to be used in paints, plastics, paper and pesticides, among other products. These include kaolin in Alto Ligonha pegmatites, diatomite in Manhiça, white marble from Montepuez and pure limestone as ground products. These opportunities should be studied to develop quality products that could be processed to make higher value by-products from these deposits.

It is also recommended that commodities such as bauxite, bentonite and diatomite should be studied, aiming at better quality, high value end-products. In the Boane area there are occurrences of perlite. However, the presence of the expandable type of perlite has not been thoroughly studied. This would have good markets for several industrial end-uses.

Import figures also show that quite a lot of gypsum is imported. There are a few known indications of gypsum, but unfortunately most of these were found to be in too deep-seated layers that cannot be exploited economically. However, there are also findings on the surface and these should be thoroughly studied.

Evate apatite in Mozambique has a very high chlorine content (1200–1400 ppm, compared to the normally allowed 200–400 ppm) and this makes its processing very corrosive. These levels are not acceptable in modern phosphoric acid and fertilizer plants producing triple superphosphate fertilizers. Nevertheless, it is recommended that the possibilities to produce single super-phosphate out of Evate raw material should be examined.

Concerning other IM commodities that have the potential to be developed, fluorite is one with a few promising occurrences, which have not properly been studied. Al-silicates, kyanite and sillimanite occurrences are also known, but detailed investigations are lacking.

Besides Montepuez marbles, other dimension stone deposits could find their way to the world market. The rehabilitation of Sena railway to the Moatize coal field will improve the economic potential of all mineral commodities near this railway. These include various types of gabbro-anorthosite in the Tete Suite, “Blue Magic” granite in Songo, carbonatites (Mt Muande-Mt Fema, Mt Muambe), limestones (Boroma, Chinguere) as well as the quality aggregates.

In general, it is concluded that when considering the potential of different IM commodities, it should be kept in mind that infrastructure is a decisive factor for any successful operation. Besides power (electricity), transportation is vitally important, especially for bulk materials, as most IM commodities are. Therefore, the overall improvement of infrastructure will be a key to developing the IM sector at large in Mozambique.

REFERENCES

Afonso, R. S. & Marques, J. M. 1993. Recursos Minerais da República de Moçambique. Contribuição para o seu conhecimento. Instituto de Investigação Científica Tropical de Portugal and Direcção Nacional de Geologia de Moçambique.1st Edition, Lisbon, Portugal, 149 p.

Bettencourt Dias, M. & Wilson, W. E. 2000. Famous mineral localities: The Alto Ligonha pegmatites, Mozambique. The Mineralogical Record 31, 459–497.

Brodoimpeks 1984. Final report on geological investigation at Muande and Monte Fema locality. ING, 1268, Tete.

Cilek, V. 1989. Industrial Minerals of Mozambique. Min. Miner. Resources, Nat. Geol.Inst. Mozambique, published by Czech Geol. Office, ISBN 80–7075–027–8, 326 p.

Customs Department, Mozambique

Geological Survey of Finland, Ministry of Trade and Industry, Finland

GTK Consortium 2006a. Map Explanation; Volume 1: Sheets 2032–2035, 2131–2135, 2231–2235, 2331–2335,2431–2435, 2531–2534 and 2632. Geology of Degree Sheets Espungabera, Chibabava, Nova Mambone, Massangena, Chidoco, Save, Bazaruto, Chicualacuala, Machaila, Chigubo, Mabote, Vilanculos, Rio Siunguédzi, Massingir, Rio Changana, Funhalouro, Inhambane, Chiembene, Chókwè, Zavala, Inharrime, Maputo, Xai-Xai and Bela-Vista, Mozambique. Direcção Nacional de Geologia (DNG), Maputo.

GTK Consortium 2006b. Map Explanation; Volume 2: Sheets 1630–1634, 1732–1734, 1832–1834 and 1932–1934. Geology of Degree Sheets Mecumbura, Chioco, Tete, Tambara, Guro, Chemba, Manica, Catandica, Gorongosa, Rotanda, Chimoio and Beira, Mozambique. Direcção Nacional de Geologia (DNG), Maputo.

GTK Consortium 2006c. Map Explanation; Volume 3: Sheets 1735–1739, 1835–1836 and 1935. Geology of Degree Sheets Mutarara, Quelimane, Namacurra/Maganja, Pebane, Marromeu/Inhaminga, Chinde and Savane, Mozambique. Direcção Nacional de Geologia (DNG), Maputo.

GTK Consortium 2006d. Map Explanation; Volume 4: Sheets 1430–1432 and 1530–1534. Geology of Degree Sheets Inhamambo, Maluwera, Chifunde, Zumbo, Fíngoè-Mâgoè, Songo, Cazula and Zóbuè, Mozambique. Direcção Nacional de Geologia (DNG), Maputo.

GTK Consortium 2007a. Geochemical and Industrial Mineral Surveys, Final Technical Report, DNG, Maputo, June 2007.

GTK Consortium 2007b. Geochemical and Industrial Mineral Surveys, Results of the Industrial Mineral Survey, DNG, Maputo, June 2007

Industrial Minerals, December 2006.

Lächelt, S. 2004. Geology and Mineral Resources of Mozambique. DGN, Maputo, 515 p. ISBN 1–919908–52–8.

Mining Weekly, May 2007.

Ministry of Mineral Resources (MIREM), Mozambique.

National Department of Mines (DNM), Mozambique.

Presley, G. C. 1991. Consultancy for testing of bentonite samples from Mozambique and recommendations for future testing for specific appliations. UNDCD Project MOZ/86/023. DNG Report No 2141/Maputo.

South Africa's Mineral Industry 2005/2006, Department of Minerals and Energy.

Yager, T. R. 2007. The Mineral Industry of Mozambique, USGS Minerals Yearbook 2006, www.usgs.gov/minerals/pubs/country.