Mozambique

Total population (July 2000 estimate): 19,105,000
Area: 801,590 km^2
Annual population growth rate (2000): 1.47%
Life expectancy at birth (1998): 43.8 years
People not expected to survive to age 40 (1998): 41.9% of total population
GDP per capita (1998): US $782

Mozambique, located in southeast Africa, has a 2,500 km coastline with the Indian Ocean and a wide coastal plain that varies in width from 150 to 600 km. The major part of the country consists of undulating plateaux. Mountainous areas occur along the border with Zimbabwe.

Mozambique is a country with a large natural resource potential. At present, the economy is largely based on agriculture, fisheries, tourism and transport. Years of civil war, droughts and floods have severely impeded the development of Mozambique. However, over the last few years Mozambique has made a successful economic recovery, and yet, according to UN statistics, 38% of the population still lives on less than US $1 per day.

The agricultural sector of Mozambique accounts for about one third of the GDP. Over 80% of farmers work their small-holdings on a subsistence basis, with an average cultivated area of less than 2 hectares. Main food crops are cassava, maize, sorghum and rice. Export crops include cotton, copra, cashew nuts and sugar, mostly cultivated by smallholder farmers and commercial farmers.

Only small parts of the mineral resource capital of Mozambique are currently been utilized. With the end of the civil war, increasing amounts of gold, gemstones, marble and graphite, as well as coal, are being mined. World-class titanium-rich sands were discovered inland, near Xai-Xai, about 250 km north of Maputo. Small-scale mining for gold has attracted many thousand artisanal miners. The International Labour Organization (1999) estimates the number of people involved in small-scale mining in Mozambique at 100,000 to 700,000.

Geological outline

Precambrian rocks underlie approximately half of Mozambique, mainly in the north and northwest of the country. They can be divided into three major structural units: Archean granite-greenstone terrane, Mesoproterozoic rocks of the Lurio Belt (Kibaran Orogeny) and the Neoproterozoic Mozambique Belt. Large parts of these Precambrian rocks were rejuvenated during the Neoproterozoic-early Cambrian Pan-African thermo-tectonic event (Bigioggero *et al.* 1989; Pinna *et al.* 1993). Karoo sediments occur in small areas of north and northwestern Mozambique. Karoo volcanics are exposed in the Lebombo Mountains, close to the border with South Africa. Mesozoic to Cenozoic sediments underlie large parts of southern and central Mozambique. Several carbonatite complexes have been delineated in Mozambique.

AGROMINERALS

Phosphates

Apart from numerous small guano deposits, there are large phosphate deposits of metamorphic, igneous and residual phosphates in Mozambique (Figure 2.10), and there are strong indications of sedimentary Tertiary phosphates in Mozambique (Davidson 1986).

1. Metamorphic phosphate deposits

- Evate. This large and probably metamorphic phosphate deposit lies within the Monapo structure, 100 km east of Nampula and close to the port of Nacala. The Evate apatite-magnetite-biotite mineralization occurs in the oval shaped 970 ± 23 million years old Monapo structure, composed of a metasedimentary sequence of biotite and graphitic gneisses with two separate marble horizons. The Evate marble deposit is 3 km long and 850 m wide. The phosphate-mineralized zones, 5-100 m thick, occur within the marble horizons. The phosphate-rich zones contain fluor-apatite as well as magnetite, forsterite, phlogopite, graphite and minor diopside (Cilek 1989; Manhica 1991). Preliminary reserve estimates indicate a resource of 155,413,000 tonnes of apatite ore at 9.32% P_2O_5, 5.76% Fe and 1.12%

TiO_2 (Manhica 1991; Ministry of Mineral Resources and Energy 1997). The reserves were calculated to a depth of 100 m above sea level. With approximately 14.5 million tonnes of P_2O_5 this is one of the largest phosphate deposits in east-central Africa.

The Evate apatite deposit is capped by a blanket of residual soil, 3-38 m thick, containing 4-64% apatite. The phosphate reserves of the residual apatite, calculated by Davidson (1986), reach 1.5 million tonnes of apatite concentrate. On a P_2O_5 basis, this would add another 525,000 tonnes P_2O_5 to the Evate deposit. The magnetite- and apatite-rich residual soils might lend themselves to simple beneficiation and concentration of apatite and magnetite.

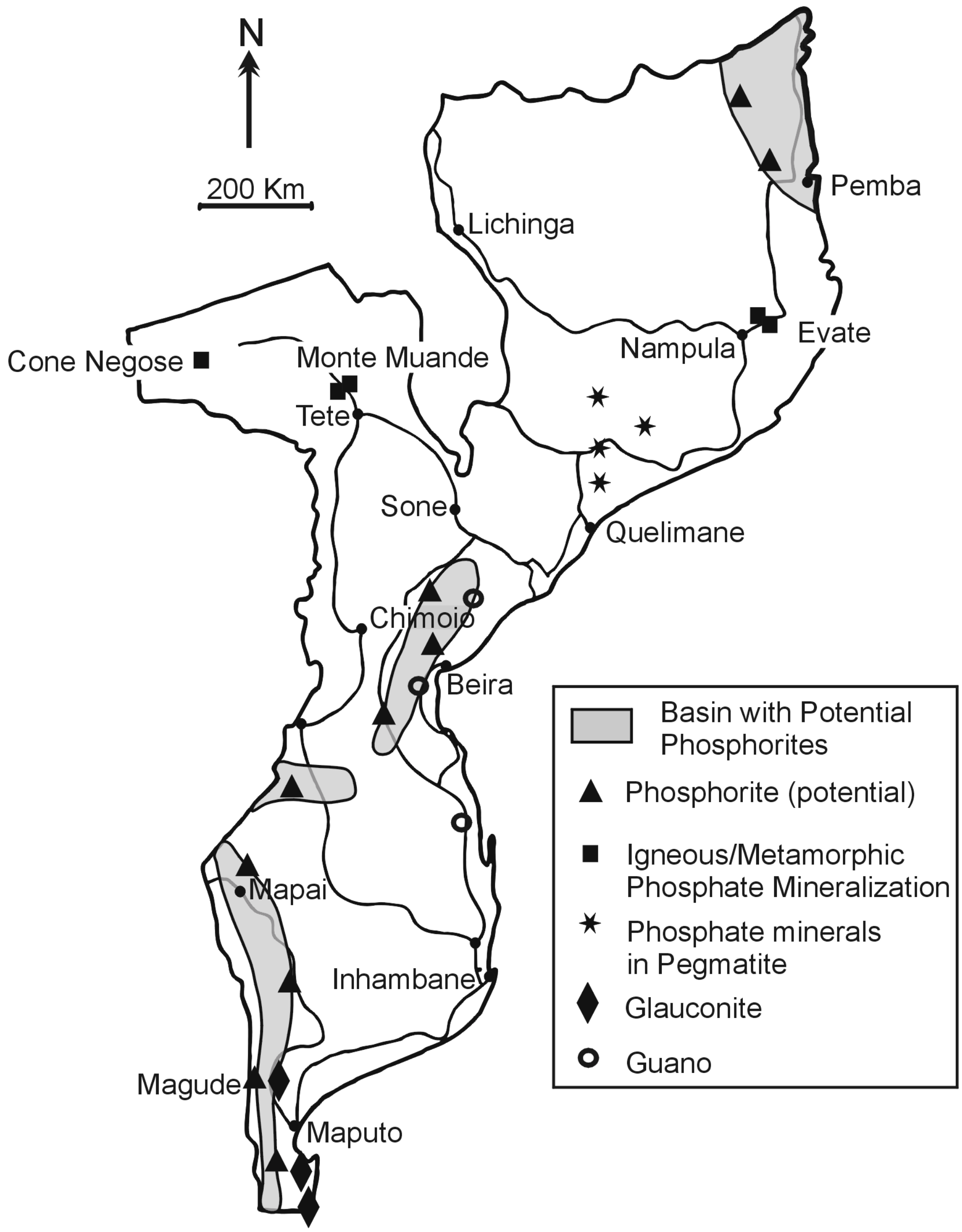

Figure 2.10: Location of phosphate occurrences and deposits in Mozambique (after Cilek 1989).

- Monte Muande. Iron and phosphate mineralization associated with Precambrian marbles is reported from Monte Muande, 30 km northwest of Tete (Staff 1984; Davidson 1986; Cilek 1989). Apatite and magnetite concentrations occur in strata-bound bodies within the foliation of the marble, close to the contact zone, with an intrusive gabbro and pyroxenite. The apatite-magnetite mineralization is localized in three beds. Low-grade phosphates occur mainly in the central bed. The genesis of this deposit is unclear. Cilek (1989) and Manhica (1991) suggest a 'pneumatolitic' type of mineralization, associated with the intrusion of a gabbro into a banded gneiss and marble sequence.

  Residual iron and phosphate accumulations cover the mineralized marble area. The mean iron concentration in these residual soils is 45.22%, and the mean phosphorus content is 5.01% P_2O_5 (Manhica 1991). Reserve calculations based on borehole data indicate 200,000 tonnes of P_2O_5 in the mineralized body (Davidson 1986).

2. Igneous phosphate deposits

Cone Negose. This Mesozoic volcanic type carbonatite, with vents and dikes cutting Karoo sediments, outcrops at Monte Negose in Tete Province, 80 km southwest of Fingoe. Phosphate enrichment (together with barite) occurs in late stage carbonatite rock (Manhica 1991). No estimates on phosphate grade and tonnage are available.

Phosphate mineralization is also reported from pegmatites in the area between Nampula and Quelimane (Cilek 1989), but their volume and economic potential is low.

3. Sedimentary phosphate deposits.

Slightly phosphatic (0.7-3.1% P_2O_5) and glauconitic (50%) sandstone beds of upper Cretaceous age (?) have been reported by de Freitas (1959) and Manhica (1991) from Magude, 29 km north-northwest of Maputo on the left bank of the Inkomati River. On the basis of their high glauconite content and their slight P_2O_5 content these 25-50 m thick beds were investigated for their potential use as a direct application fertilizer (Notholt 1994).

The Rovuma Basin in north-northeast Mozambique bears some similarities to the lower Cretaceous phosphatic beds of the Mahajanga (Majunga) Basin in Madagascar and the possibility of finding phosphorites of similar age in this area has been suggested by Notholt (1994).

Based on paleogeographic investigations, studies of existing borehole data and geological and geophysical information, Davidson (1986) concluded that an extensive phosphorite deposit might be present in the southern Mozambique Basin. The glauconite-bearing Eocene Cheringoma Formation, which contains fossil fish and teeth beds, is seen as an excellent potential source rock for phosphorites in the southern basin of Mozambique.

Other agrominerals

Guano

Manhica (1991) reports guano deposits from several localities of Mozambique. The largest guano accumulations are found in caves of the Cheringoma Plateau area. Estimated reserves are 600,000 tonnes (5.14% P_2O_5, 2.74% NO_3, and 1.37% K_2O). Reserves of 132,700 tonnes are also reported from the Buzi area (3.88% P_2O_5, 3.26% NO_3, 1.52% K_2O). Nunes (1961) reports the existence of bat guano in caves of the Jofane formation near Vilanculos with estimated reserves of 22,000 tonnes at 8 to 13% P_2O_5. More recent data from Manhica (1991) indicate 30,000 tonnes with 3.32% P_2O_5, 5.22% NO_3 and 2.95% K_2O

from this area. Between 1953 and 1960 some 6,000 tonnes of guano were excavated from the Vilanculos caves and 1,000 tonnes from the Buzi area (Manhica 1991).

Limestone/dolomite

There are three types of limestone/dolomite resources in Mozambique: sedimentary, metamorphic and igneous.

Sedimentary limestones occur extensively in the Cretaceous and Tertiary basin of Mozambique. The Eocene limestones of Salamanga, south of Maputo, are used in the cement industry. Extremely large deposits (several hundred million tonnes) of Eocene limestone occur along the Cheringoma Plateau south of Inhaminga. Other large limestone formations include the Miocene Jofane Formation, Pliocene-Pleistocene limestones near Nacala, and small Miocene occurrences along the coast between the Tanzanian border and Pemba.

Metamorphic limestone and dolomite resources are mainly found in the Precambrian of northern and central Mozambique (Figure 2.11). Proterozoic marbles and dolomitic limestones and dolomites are found in the following areas:

- approximately 50 km north of Lichinga in the Serra Geci area (Pinna *et al.* 1993),
- near Montepuez,
- near Canxixe,
- north and northwest of Tete (in the Massamba and in the Monte Muande area),
- in the Monapo structure (see phosphates),
- at the Lurio River near Namapa,
- near Chire at the border with Malawi,
- between Massanga and Mungari,
- near Fingoe.

Some of the marbles are being used for the production of lime (Lurio-Namapa; at Malula, north of Lichinga; and in parts of the Monapo structure).

The main igneous limestone/dolomite resources are found at Monte Muambe and Monte Xiluvo. Monte Muambe lies some 30 km southeast of Tete, and is not to be confused with the Monte Muande magnetite-apatite deposit, 30 km northwest of Tete. The almost circular Monte Muambe carbonatite complex is 6.5 km in diameter and contains economic quantities of fluorite (Markwich 1996). The central core of the complex is composed of carbonate rock (Gittins 1966).

The Monte Xiluvo carbonatite complex, which lies close to the Beira-Mutare railway line, consists of a circular ring of hills about 5 km in diameter. The central plug is made up of carbonatite (Gittins 1966). A quarry supplying carbonates for the construction industry has been in operation for many years at this location (Cilek 1989). Some of the more apatite-rich carbonatites have been proposed for use in agriculture (Manhica 1991).

In addition to the above named carbonate resources there are numerous lacustrine limestones and coral limestones along the coast of Mozambique. A compilation of limestone/dolomite resources is listed in Cilek (1989) and Markwich (1996).

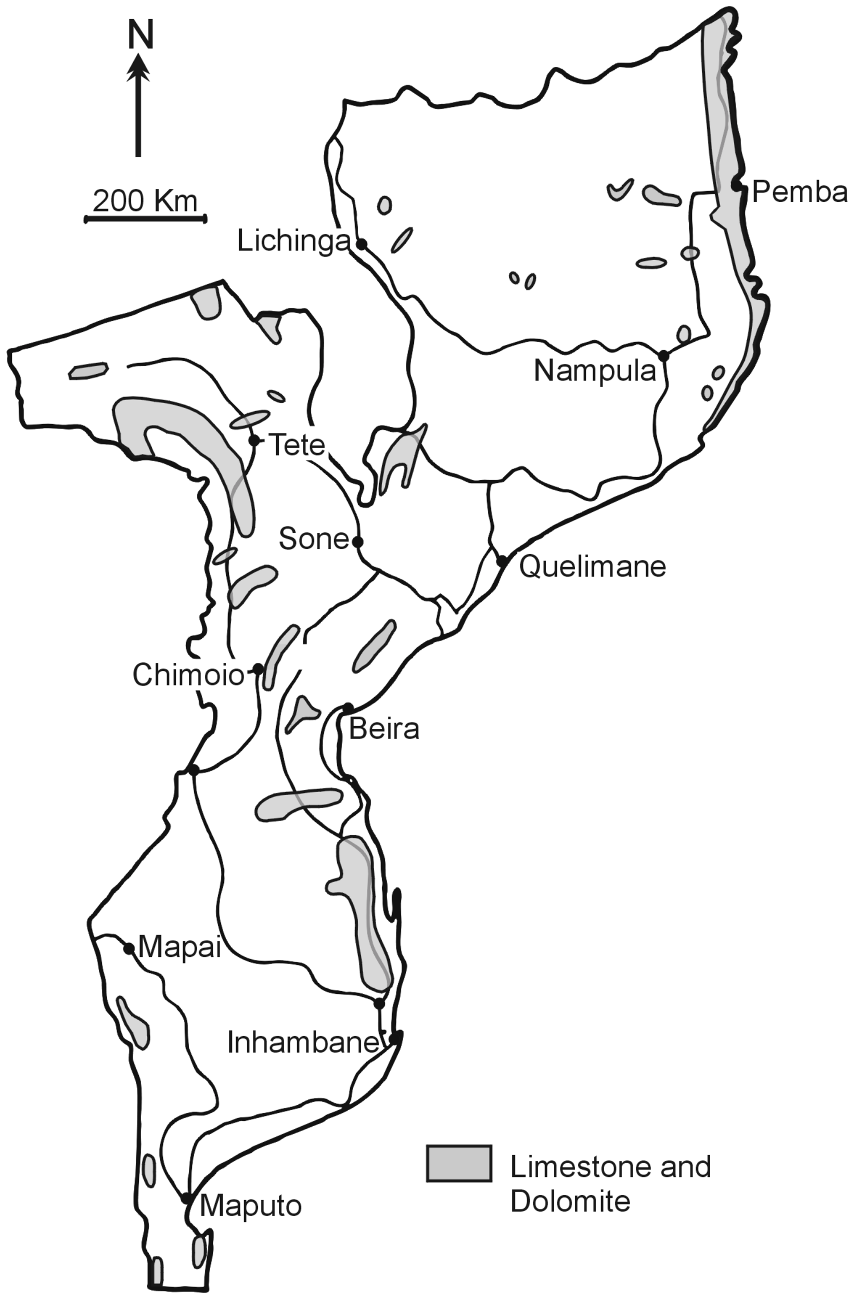

Figure 2.11: Distribution of limestone and dolomite deposits in Mozambique (after Cilek 1989).

Gypsum/anhydrite

Cilek (1989) describes several gypsum and anhydrite occurrences from oil and gas exploration boreholes in the coastal zone of Mozambique. The most extensive gypsum and anhydrite deposits are of Oligocene/ Miocene age and occur in the evaporite sequence of the Temane Formation. Most extensive are the 10-15 m thick gypsum and anhydrite beds south of the Save River and Nova Mambone. The reserves of gypsum and anhydrite exceed 250 million tonnes (Cilek 1989). Unfortunately these beds occur at depth of 150-200 m, but might occur closer to the surface in other places (Cilek 1989).

Glauconite

Many of the Cretaceous and Tertiary sediments from Mozambique contain glauconite, specifically the Grudja and Cheringoma Formations (Flores 1973) with some beds containing up to 50% glauconite (Manhica 1991). Their potential agronomic usefulness as soil amendments is based on their elevated potassium and phosphorus contents.

Perlite

Perlite, a volcanic glass that will expand at 800-1,100^{o} C to a lightweight foamy rock material used in the construction and horticultural industry, occurs in the Lebombo Mountains in Mozambique and neighbouring South Africa. In the Lebombo Mountains, perlite is found in association with obsidian and bentonite deposits of the Karoo Supergroup. The perlite resources of Mozambique are largely confined to the deposits around Muguene, west of Maputo. At Muguene South, the reserves of perlite are 100,000 tonnes in the proven reserve category and 400,000 tonnes probable reserves. At Muguene North, the reserves of vitrified volcanic glass are 250,000 tonnes in the proven category and 1 million tonnes probable reserves (Cilek 1989). The bulk density of the expanded perlite from Muguene is 6.84 lb/cubic foot (0.109 g/cm $^{-3}$) which indicates low expansion properties and low quality. A small furnace was operated at Muguene and produced small amounts of perlite in the 1960s.

Extensive obsidian resources with potential perlite properties were discovered in the 1980s near Ressano Garcia, along the Maputo-South Africa highway. However, technical tests of this glassy volcanic material revealed that they had no expansion properties and were therefore unsuitable for the horticultural industry (Cilek 1989). In general, the known perlite resources of Mozambique are small and of low suitability for horticultural industries.

Natural zeolites

The Lebombo volcanics at the border with South Africa are made up of a sequence of extrusives and tuffs. Altered rhyolitic tuffs and perlites of the Lebombo Mountains in the adjacent areas of South Africa are the source for commercial zeolite extraction (Pratley, pers. comm., 1985).

Agromineral potential

The potential for developing Mozambique's geological resources for long-term sustainable agricultural needs is good. There are several extensive phosphate deposits of sedimentary, metamorphic and igneous origin, which could be used for small-scale agromineral development. The very extensive phosphate deposit of Evate (with more than 155 million tonnes of phosphate-bearing ore) and other deposits should not only be investigated for large-scale phosphate extraction, but also on their potential for small-to medium-scale development. The extensive glauconite-bearing Eocene Cheringoma Formation with fossil fish and teeth beds is seen as an excellent indication of finding phosphorite resources in the southern basin of Mozambique and detailed exploration on this target is strongly recommended.

Limestone/dolomite resources are scattered throughout the country and increased efforts should be placed on testing individual resources as to their agronomic efficacy as liming materials, especially on acid soils. Some of these resources are already developed for industrial purposes and their agricultural potential should be assessed. Appropriate and adapted limestone/dolomite crushing and grinding technologies can be developed to provide liming materials to farmers cultivating acid soils.

Glauconitic and slightly phosphatic sandstones of upper Cretaceous age near Maputo should be investigated with regard to their potential use as low-grade slow release 'petrofertilizers.' Their application could be especially interesting for crops with high K requirements like bananas and for perennial crops like coconut.

Exploration for natural zeolites in the Lebombo Mountains near the South African border should occur.

The idea of erecting artificial roosting platforms for sea birds to produce guano, like in Namibia, should be studied.

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