

Mali

Total population (July 2000 estimate): 10,686,000

Area: 1,241,232 km²

Annual population growth rate (2000): 2.98%

Life expectancy at birth (1998): 53.7 years

People not expected to survive to age 40 (1998): 33.1% of total population

GDP per capita (1998): US \$681



Mali is a landlocked country in central West Africa. The Sahara desert and some mountainous areas occupy the northern part of the country. The Niger River Valley in the centre of the country crosses Mali and provides essential water and nutrient resources. Only in the extreme south is rainfall sufficient to cultivate crops without irrigation. The vegetation ranges from desert plants in the north to tall grass and savannas in the south. Annual rainfall in the north is below 200 mm; in the south, close to the border with Côte d'Ivoire, it reaches 1300 mm.

Mali's soil fertility is generally poor. Characteristically, the soils are mainly sandy, the soil organic matter is very low and soil pH values range from 4.3-6.3. One of the major limiting factors for agriculture is the low phosphorus status of the soils. The lack of precipitation is another major constraint to sustainable crop production in large parts of Mali.

The economy of Mali is mainly based on agricultural production and stock rearing. In 1999, the agricultural sector accounted for 48% of the GDP. Some 85% of the population is involved in livestock raising, crop production and fishing. The major crop production systems vary with the available soil moisture. Rotation of groundnut and pearl millet is prominent in the centre of the country with annual precipitation varying between 500 and 800 mm. Rotation of maize-cotton is common in the southern sub-humid to humid rainfall zone (> 1000 mm). The northern limit of the major cash crop of Mali, rainfed cotton, is dictated by the line of 700 mm annual precipitation.

Mali's mineral resource development plays an increasingly important role in the economy of the country. Gold is the main mineral commodity for export. In 1995, gold made up 95% of Mali's mineral production. With the opening of the Sadiola gold mine in 1997, Mali became Africa's fourth largest gold producer, behind South Africa, Ghana and Zimbabwe. In addition, considerable amounts of gold, found near the surface, is mined by artisanal miners. The International Labour Organization (1999) estimated the number of people involved in small-scale mining at 100,000.

Geological outline

The geology of Mali includes a wide range of rock types. Archean and Paleoproterozoic rocks underlie large parts of western and central Mali, and sediments of the intracratonic Taoudenni Basin occupy large parts of central and north Mali. The Taoudenni Basin is mainly composed of Neoproterozoic to lower Cambrian, and Phanerozoic platform sediments. The Neoproterozoic to lower Cambrian contains a sequence of tillites, limestone (with barite), and chert, a sequence known in other parts of West Africa as 'triad.' Precambrian rocks, deformed during the Neoproterozoic Pan-African collision event, as well as Cretaceous and Tertiary sediments, underlie parts of northern and eastern Mali. Devonian and Carboniferous sediments are found in areas around Taoudenni in the north of the country.

AGROMINERALS

Phosphates

Mali hosts voluminous high-grade Tertiary sedimentary phosphates. These up to 2.2 m thick phosphorites are located in eastern Mali. They extend for more than 400 km between Asselar to Telatai and the Niger border (Pascal and Traore 1989). The best-known phosphate deposits, of Eocene (Lutetian) age, occur in the Tilemsi River Valley (Figure 2.9).

The phosphorite deposit on the east bank of the (dry) Tilemsi River Valley has been studied in detail by many geoscientists. Technical and economic studies were undertaken by Kloeckner Industrie (1969), by the German Technical Cooperation (GTZ 1977), and by the International Fertilizer Development Center (IFDC 1977).

The best-studied area of phosphate rocks in the Tilemsi area is that of Tamaguilel ($17^{\circ} 40' N$; $0^{\circ} 15' E$) (Figure 2.9). Here, the unconsolidated phosphatic sediments consist mainly of fish and reptile bone debris as well as coprolites. Detailed mineralogical investigations have identified the phosphate mineral as francolite with crystallographic unit-cell a -value of 9.331 \AA , indicating a relatively highly reactive PR. Indeed, the neutral ammonium citrate solubility of Tilemsi PR is high at $4.2\% \text{ P}_2\text{O}_5$ (McClellan and Notholt 1986), making it suitable as direct application phosphate fertilizer.

The mean grade of the phosphatic layers at Tamaguilel is $27\% \text{ P}_2\text{O}_5$. The phosphatic ore is not calcareous. In places the phosphates contain relatively high Fe-concentrations: up to $8\% \text{ Fe}_2\text{O}_3$ in the Tamaguilel area, up to 20-30% in the Telatai area. Some parts of the phosphatic layers are also high in manganese.

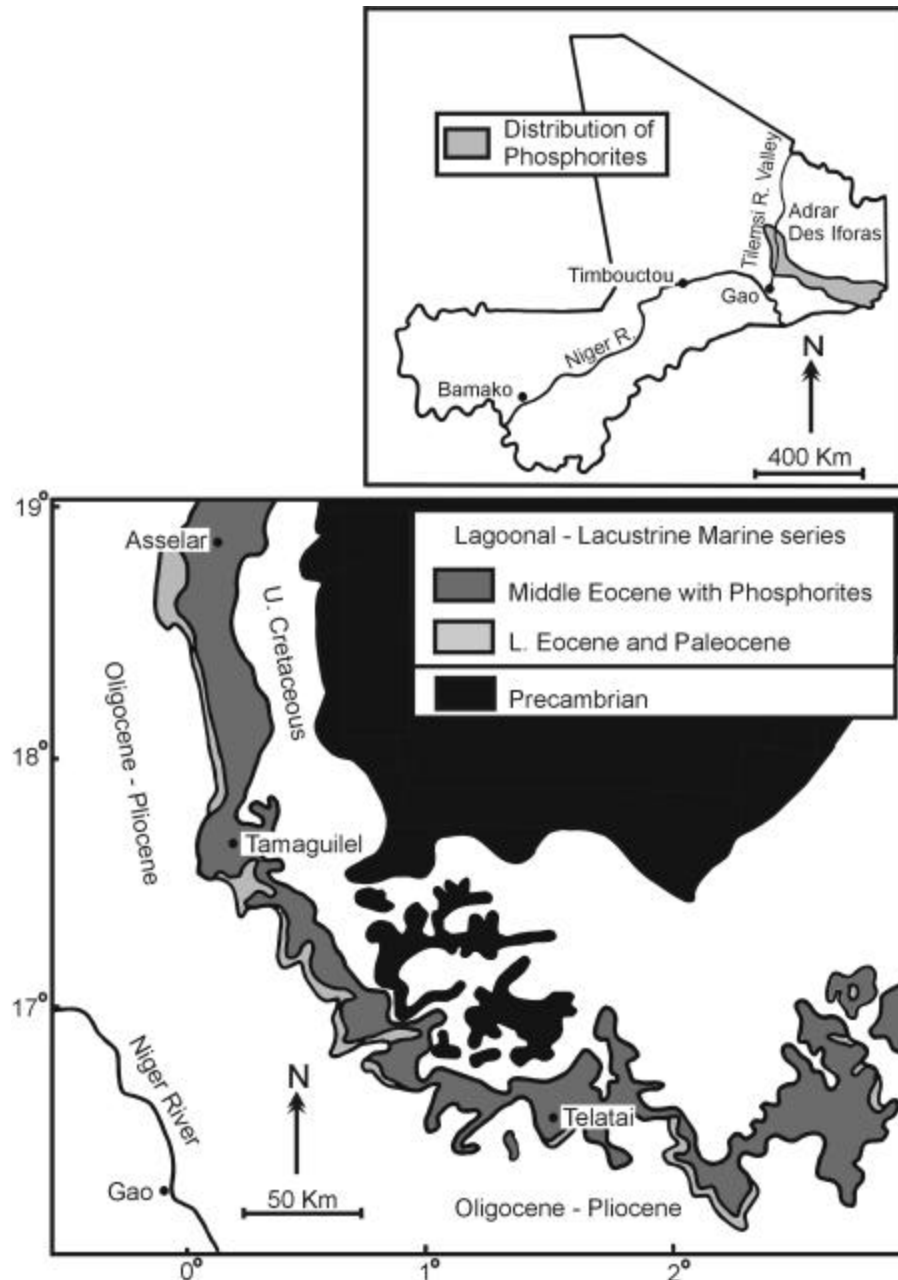


Figure 2.9: General geological setting of the phosphate mineralization of Eastern Mali (after Pascal and Traore 1989).

The surface area of Tilemsi PR is the highest of the PRs of West Africa reported by Truong and Montange (1998): $26.4 \text{ m}^2 \text{ g}^{-1}$ for the 0.5 mm fraction, and $34.2 \text{ m}^2 \text{ g}^{-1}$ for the 0.1 mm fraction. The P uptake rate from applied Tilemsi PR and the agronomic effectiveness is correspondingly very high (Truong and Montange 1998).

Phosphate reserves are in excess of 20 million tonnes, with some 12 million tonnes at 25% P_2O_5 at Tamaguilel alone. Approximately 10 million tonnes at the Tamaguilel deposit are located beneath 15 m of overburden (Sustrac 1986).

The deposit is located in a remote area and the infrastructure is not well developed as yet. A crushing and bagging plant was built at Bourem in December 1980 and continued producing phosphate at a rate of 1,000-3,000 tonnes per year until 1995. The mill has a processing capacity up to 30,000 tonnes per year.

Direct Application of Tilemsi Phosphate Rock

Tilemsi phosphate rock (Tilemsi PR) was tested as direct application phosphate fertilizer already in the early 1970s (Pieri 1973; Thibaut *et al.* 1980). Between 1982 and 1986, experiments with Tilemsi PR were carried out at 10 experimental stations in Mali in collaboration between the Institut d'Economie Rural (IER), the International Fertilizer Development Center (IFDC) and the International Development Research Centre (IDRC) (Diamond *et al.* 1989). The results show that the relative agronomic effectiveness (RAE) of directly applied ground Tilemsi PR varied from crop to crop (for instance 64-100% for groundnuts, 71-76% for millet, 64-100% for sorghum and 73-98% for maize). The average RAE of Tilemsi PR when compared to TSP was 78%. This means that Tilemsi PR was 78% as effective in increasing crop yields as TSP. Management practices can influence the effectiveness of Tilemsi PR. Banding of Tilemsi PR was less effective than incorporating (Chien and Menon 1995). Timing of application of Tilemsi PR was tested by Hellums (1991) on flooded rice. Tilemsi PR performed well when applied 2 weeks before flooding, but was largely ineffective when applied at or after flooding.

Agronomic and economic evaluations by Bationo *et al.* (1997) clearly show that crop yields using Tilemsi PR in direct application are comparable to those of recommended imported fertilizers for cotton or cereal crops. Direct application of Tilemsi PR is relatively profitable in comparison with recommended imported fertilizers (Bationo *et al.* 1997), specifically in areas with sufficient rainfall. The researchers recommend conducting a technical and economical feasibility study of small-scale production of compacted fertilizers in Mali using Tilemsi PR as the P source. Initial tests carried out in Zimbabwe in 2001 proved that the Tilemsi PR is amenable to blending with more soluble P+N fertilizers and can be effectively pelletized using locally produced appropriate technology (van Straaten, unpublished).

Other phosphates

Of minor importance are the small phosphate occurrences in the middle Devonian limestones and in small carbonatite plugs. Middle Devonian limestones in areas north and east of Taoudenni reportedly contain local oolitic phosphates (Wolff 1996). The extent of these phosphatic limestones is not known, although phosphatic rocks of similar age (Devonian/lower Carboniferous) have also been documented from the Agades region of Niger (see chapter on Niger).

Other rocks containing small amounts of phosphate minerals are the carbonatites north of Tessalit (Sauvage and Savard 1985), but they have no economic significance.

Other agrominerals

Limestone/dolomite

The limestone and dolomite resources of Mali are extensive. Several large limestone and dolomite deposits occur in the western part of the country, close to the towns of Kayes, Diamou and Bafoulabe. The Gangotery deposit, near Bafoulabe, reportedly contains 7 million tonnes of limestone. It has been exploited for the cement industry located in Diamou since 1969 (Wolff 1996). Large dolomite occurrences are located some 80 km from Dioila (6°25' W; 12° 4' N), and in the centre of the country, near Goundam and Tomboctou, there are several large limestone to dolomitic limestone deposits. The dolomitic marbles and dolomites near Hombori and Douentza appear to be very extensive. The very small carbonate occurrences associated with carbonatites northwest of Tessalit (Sauvage and Savard 1985) are found in very remote locations and have no practical significance.

Gypsum

Gypsum reserves exceeding 2 million tonnes (Keita 1994), with an annual production of 700 tonnes per year (van Oss 1993), occur in northern Mali, near Tessalit. Also, gypsum has been described from salt lakes near Taoudenni. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), bassanite ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) and anhydrite (CaSO_4) have been reported from the Taoudenni-Arogott basin in northern Mali by Mees (1998).

Potash

A small sylvite (KCl) deposit has been reported from the salt depression of Taoudenni in the far north of Mali (Johnson 1995). Unconfirmed reports of Ivanov (1969) speak of potash salts reaching 180 million short tons. The author reported these large resources from an unspecified location 'between Timbuktu and Taoudenni.'

Agromineral potential

The potential for further development of the Tilemsi phosphate resource is very good, despite the remote location of the deposits. The phosphates are of excellent quality and suitable for small-scale processing and application on P-deficient soils. One of the disadvantages for handling the PRs is the powdery nature of the Tilemsi PR. This may be overcome by appropriate pelletizing techniques and might increase the marketability of the final P products. Technical studies for small-scale, low-cost crushing/grinding and production of compacted or pelletized Tilemsi PR fertilizers need to be conducted. Additionally, biological modification techniques and blending of Tilemsi PR with biological 'waste' products should be envisaged.

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