Senegal

Total population (July 2000 estimate): 9,987,000
Area: 196,190 km²
Annual population growth rate (2000): 2.94%
Life expectancy at birth (1998): 52.7 years
People not expected to survive to age 40 (1998): 28% of total population
GDP per capita (1998): US $1,307
Senegal is located at the western-most part of Africa at the Atlantic Ocean. The Senegal, Gambia and Casamance Rivers drain from extensive inland plains with altitudes of less than 200 m. In the south-east of the country, plateaux with altitudes up to 600 m form the foothills of the north-south striking Bassaride mountain range. North of the Gambia River, much of the land is barren except for the floodplains of the Senegal River.

The agricultural sector, dominated by crop production and coastal fishing, as well as the tourist and mining sectors, forms an important part of the Senegalese economy. In 1999, agriculture accounted for 18% of the GDP, and employed more than 60% of the working population. The staple food of the Senegalese is rice, followed by millet and sorghum. The main export crops of Senegal are groundnuts and cotton. Extensive sugarcane production provides a large part of the total national sugar requirement.

The production and export of phosphate rock, and phosphate-based fertilizers dominate the mineral industry of Senegal and phosphate production has been relatively stable over the last few decades. Small occurrences of gold and industrial minerals are also reported from Senegal. Exploration for hydrocarbons has revealed limited offshore oil resources and substantial amounts of onshore natural gas (106 billion cubic feet).

**Geological outline**

Senegal is dominated by two major geological units: the folded Precambrian basement in the east of the country, and the shallow-dipping Upper Cretaceous to Quaternary sediments in most of the central and western parts of Senegal.

The Precambrian in the east and southeast of the country is subdivided into the Paleoproterozoic Birimian volcano-sedimentary sequence, the Neoproterozoic Madina-Kouta Basin Series, and the two folded Neoproterozoic/Cambrian Pan-African mountainous ranges, the Bassaride Branch and the Koulonton Branch. The Lower Cambrian is represented in the Faleme Basin with tillites, cherts and limestones. Between the two Neoproterozoic/Cambrian Pan-African sequences lies a basin filled with Cambro-Ordovician conglomerates, mudstones and sandstones.

**AGROMINERALS**

**Phosphates**

There are several phosphate occurrences and deposits in Senegal (Figure 2.14). The four main phosphate deposits are:

- the Neoproterozoic/Cambrian phosphates in the Namel area, southeast Senegal,
- the Eocene phosphate deposits along the Senegal River, including the ‘Matam’ deposits,
- the Eocene primary phosphate deposits in western Senegal, mined at Taiba and Lam Lam,
- the aluminous phosphates of Thies, weathering products of the Eocene phosphates, found also in western Senegal.

Senegal is one of the major phosphate producers in sub-Saharan Africa. In 1997, the total phosphate production from Senegal was 616,700 tonnes (British Geological Survey 1999), down from approximately 1 million tonnes of phosphate concentrate in 1993, which were exported to Canada, Australia, Mexico and China. A high proportion of the concentrate is used for the industrial processing and production of soluble P-fertilizers, for instance SSP, TSP, DAP and NPKs. Most of the processed P-fertilizers are exported.
The phosphates of Taiba.

The phosphate deposit of Taiba was discovered in 1948 and up to now has been the main phosphate mining area of Senegal. The deposit is mined by the Compagnie Sénégalaise des Phosphates de Taiba (CSPT).

The phosphate beds are part of a very extensive phosphate-bearing area northeast of Dakar. Phosphate mining takes place mainly in the Keur Mor Fall deposit area at Taiba, some 110 km by rail from Dakar. Here, the Middle Eocene (Lutetian) phosphatic sequence can be divided into three major beds. They are, from top to bottom:

- 2-3 m homogenous phosphates,
- heterogeneous phosphatic ore containing flint,
- thin indurated coprolitic phosphates (phosphate gravel), 3-4 m thick.

Below the 5-12 m (average 7 m) thick phosphatic beds are Middle Eocene finely laminated ‘paper’ clays, made up largely of palygorskite (attapulgite). Above the phosphates are up to 25 m thick Quaternary aeolian sands (Pascal and Sustrac 1989). The proven reserves of the Keur Mor Fall deposit are 100 million tonnes with ore grades ranging from 18-39% P₂O₅ (McClellan and Notholt 1986). The average grade is 24% P₂O₅.
The neutral ammonium citrate solubility of the Taiba phosphate concentrate (37.4% P$_2$O$_5$) is 3.1% P$_2$O$_5$ (McClellan and Notholt 1986). The Cd content of the Taiba phosphates are elevated, ranging from 60-115 mg/kg, and averaging 87 mg/kg.

**The aluminous phosphates of Thies.**

Aluminous phosphatic rocks, resulting from long periods of weathering of phosphatic sediments, cover large parts of the Thies Plateau of western Senegal. The city of Thies is located in the centre of this extensive, elevated area. Natural outcrops of the aluminous phosphates are sparse. The best exposures are seen in open pits between Lam Lam and Pallo, approximately 15 km northwest of Thies.

The aluminous phosphates of Thies are the result of lateritic weathering of the underlying Middle Eocene to Oligocene argillaceous phosphatic sediments. The weathering episode is estimated to have occurred from Middle Miocene to Lower Pliocene. For his doctorate thesis, Flicoteaux (1982) studied the genesis of this deposit in detail and found at least four stages of weathering: apatite leaching (stage 1), accumulation of kaolinite and Fe-millisite (stage 2), ‘ochreous’ aluminous phosphate development (stage 3), and leaching into ‘white facies’ phosphates in topographic depressions (stage 4). The main phosphatic weathering products are Ca-millisite, Sr-crandallite and wavellite. Mineralogical studies showed that the neutral ammonium citrate solubility of the typical Al-phosphate product of Pallo (32.0% P$_2$O$_5$) is high at 12.0% P$_2$O$_5$ (McClellan and Notholt 1986).

The Société Sénégalaise des Phosphates de Taiba (SSPT) mines these aluminous phosphates in open-pit operations near the village of Pallo, 10 km northwest of Thies. The mineable phosphate ore at Pallo is 10 m thick and has an overburden of 3 m. The aluminous phosphates are crushed, calcined to increase the grade to 34% P$_2$O$_5$ and also to increase citrate solubility, and marketed as ‘Phosal’ for use as a fertilizer or ‘Polyphos’ used in animal feed (Flicoteaux and Hameh 1989).

Proven aluminous phosphate reserves in the 32,000 hectare concession amount to 50 million tonnes with 29% P$_2$O$_5$ (Flicoteaux and Hameh 1989).

Between 1979 and 1983 the annual production of crude phosphate ore from the aluminous phosphate deposit of Pallo was 180,000-280,000 tonnes, and the corresponding calcined ore between 78,000 and 140,000 tonnes (Flicoteaux and Hameh 1989).

**The Lam Lam phosphate deposit.**

Unweathered Ca-phosphates are mined by the Société Sénégalaise des Phosphates de Taiba (SSPT) near the village of Lam Lam, northwest of Thies. These unweathered phosphates resemble the phosphates of Taiba and occur as 7 m thick layers under a thick iron crust. Proven reserves of this deposit are 4 million tonnes of marketable product with an average grade of 33% P$_2$O$_5$. Only 1.5 million tonnes of these reserves have an overburden of less than 24 m (McClellan and Notholt 1986).

**The Matam (Ouali-Diala) phosphate deposits.**

The Matam phosphate deposits, described in detail by Pascal and Cheikh Faye (1989), occur on the left bank of the Senegal River. The phosphate beds can be traced over a distance of at least 100 km (Figure 2.14). The phosphatic layers are 4-16 m thick. At places they lie at shallow depth along the slope of the Senegal River. In other places they occur more than 30 m below the flat and monotonous landscape. The first systematic prospecting took place between 1962 and 1966, and further work between 1980 and 1984 resulted in the delineation of this extensive phosphate deposit (Pascal and Cheikh Faye 1989).
Palaeontological studies on shark teeth assign the Matam phosphates to the Lower Eocene, but some reworked coarse-grained coprolitic phosphates also occur in the Quaternary. The main phosphate beds in the N’Diendouri and Ouali Diaa area are slightly indurated, light grey, coarse grained ‘arenites.’ Here, the phosphatic sequence is exposed at or near to the surface. The main phosphatic unit is 6-10 m thick in a clay-rich matrix containing mainly palygorskite (attapulgite) and montmorillonite. The phosphate mineral has been identified as francolite. The neutral ammonium citrate solubility of the Matam phosphates (28.7% P₂O₅) is relatively high, 4.5% P₂O₅ (McClellan and Notholt 1986) indicating that the chemical and mineralogical composition of the phosphate rocks is favourable for direct application in agriculture (Pascal and Cheikh Faye 1989). The trace element content of this phosphate is low, with Cd concentrations of less than 5 mg/kg, and U concentrations of less than 40 mg/kg

**Figure 2.15:** Geological setting of phosphate mineralization along the Senegal River near Matam, Senegal (after Pascal and Cheikh Faye 1989).

Pascal and Cheikh Faye (1989) reported seven major occurrences on the left bank of the Senegal River, two of them regarded as major deposits with reserves of more than 10 million tonnes. The overall reserves of the phosphates between N’Diendouri and Ouali Diaa exceed 40 million tonnes at a grade averaging 28.7% P₂O₅. The deposit could be worked by open pit methods with a mean overburden-to-ore ratio of 4.5:1 (Pascal and Sustrac 1989). Industries Chimique du Sénégal (ICS) plans a new US $100 million phosphate mine in the Matam area (Leaky and Harrison 2000).
The Namel phosphate deposit.

The phosphate deposit near Namel in southeast Senegal was discovered during a systematic geochemical and geophysical exploration campaign in 1975. The Neoproterozoic to Lower Cambrian (approximately 650 million years of age) phosphates occur at the western edge of the Precambrian basement zone at the Kedougou inlier in eastern Senegal/northern Guinea (Pascal and Sustrac 1989). The rock sequence unconformably overlies the Paleoproterozoic (Birimian) basement. Below the phosphate sequence lies a 3 m thick tillite bed. It is overlain by 18 m of fine-grained siliceous rocks, 9 m of phosphatic pelites, 2 m of calcareous phosphates (15% P₂O₅) and 8 m coarse phosphates (22-32% P₂O₅). The phosphate layers with over 20% P₂O₅ contain abundant silica (Slansky 1986). The phosphate grains vary in size from 50 µm to several mm. The CaO/P₂O₅ ratios vary from 1.2 in the upper weathered zone to 1.8 at depth where carbonate gangue is present. Mudstones and dolomites overlie the phosphates.

Mineralogical studies of phosphate samples collected from the surface show deformed grains of recrystallized fine-grained apatite in a siliceous matrix (McClellan and Saavedra 1986). Crystallographic data indicate a nearly pure fluor-apatite (unit-cell a-value = 0.9373 Å). Banded calcareous phosphorites samples from 8 m depth show that the apatite is a low carbonate-substituted francolite with a crystallographic unit-cell a-value of 0.9360 Å (McClellan and Saavedra 1986).

The best exposure of this phosphate sequence is in the vicinity of Namel. Here, the phosphates are exposed over a length of 1 km on the east side of the Namel Valley. No reserve data are available.

Other phosphate resources

There are several more Eocene phosphate ‘occurrences’ reported in Senegal, for instance near Thies, Sebikotane, Pointe Sarene and southeast of M’Bour (McClellan and Notholt 1986).

Notholt (1994) reported 20 million tonnes of phosphate resources from ‘wastes’ in the western part of Senegal. Material that is finer than 40 µm is currently discarded as ‘waste’ although it contains 26% P₂O₅. No more details on this potential resource are given.

Current mining operations

There are several phosphate companies operating in Senegal.

- Compagnie Sénégalaise des Phosphates de Taiba (CSPT) mines and concentrates the Ca-phosphates at Taiba. The Senegalese government is a 50% shareholder of this company, which employed 1,400 persons in 1994. The mine and concentration-drying plant is located at Taiba. The concentrate is shipped by rail to the Dakar stockyard from where it is shipped abroad.
- Société Sénégalaise des Phosphates de Thies (SSPT) mines mainly palygorskite (attapulgite) and minor amounts of Al-phosphate from Thies. In 1994, the government and the French company Rhone Poulence were shareholders and employed 230 persons.
- Industries Chimique du Sénégal (ICS) manufactures phosphate fertilizers from phosphate concentrates supplied by CSPT. ICS is located next to the CSPT mine site. Sulphuric acid and phosphoric acid plants are located at Darou Khoudoss and the fertilizer unit is located at Mbao. Shipping of the various fertilizers, including NPK, DAP, TSP and SSP, is from the free port of Dakar. ICS plans a major extension of its mine capacity and chemical facilities (Leaky and Harrison 2000)
Limestones

Small occurrences of dolomitic limestones and marbles are known from the Paleoproterozoic in the Kedougou inlier in southeast Senegal, close to the border with Guinea. This greyish marble, 25 km west of Kedougou, has been exploited for the production of lime in the past (Roth 1996). Upper Cretaceous to Paleocene marly limestones occur east of Dakar in the Popenguine-Thies area. The Paleocene limestones are massive and coarse-grained and are up to 40 m thick. Eocene limestones occur in several locations in Senegal, east of Dakar in the area of Rufisque, and along the banks of the Senegal River (Roth 1996).

Other agrominerals

Peat resources, estimated at 52 million m³ occur along the coast of Senegal. A surveying permit was granted to Cie des Tourbières du Sénégal (Mining Annual Review 1994).

Phospho-gypsum

Large amounts of phospho-gypsum are produced annually by Industries Chimique du Senegal (ICS). Parts of these ‘waste’ products are currently being applied on Senegalese soils within the framework of the national program aiming at increasing agricultural production in Senegal. Long-term experiments with phospho-gypsum were started in 1997 and are ongoing (Sene et al. unpublished). In 1999, the utilization of phospho-gypsum in Senegal was 62,153 tonnes (Diop, pers. comm. Oct. 2001).

Agromineral potential

The agromineral potential of the locally available phosphate resources is high not only for export but also for domestic use. Many small sedimentary phosphate beds occur in western Senegal, mostly, however, under considerable overburden. Extensive phosphatic sequences occur along the Senegal River and in the southeast of the country. Of considerable interest are the layered, near-horizontal Eocene phosphate beds close to the surface along the Senegal River. It is recommended that these layers, often covered by slope detritus, should not only be investigated for their large-scale extraction but also with the aim of small-scale excavations and local use in the agricultural area along the Senegal River.

The layered Precambrian Namel phosphates exposed over a length of 1 km on the western slopes of the Namel Valley should be evaluated as to their suitability for small-scale phosphate extraction and use.

The usefulness of these phosphates depends largely on ease of extraction, and proximity to suitable soils in agricultural areas with P-deficiencies. The mineralogy indicates that most of these phosphates are suitable for direct application and/or low-cost modification techniques. As part of ongoing projects of the Rodale Institute, Taiba PR is currently applied directly, or in combination with manure (Diop 1999).

The ‘wastes’ of the phosphate industry in western Senegal, mainly phosphate fines and phospho-gypsum, need further field testing as potential low-cost P-fertilizers, as soil amendment for alkaline soils and for groundnut production. Alternative further processing of phospho-gypsum ‘wastes,’ for instance by the Merseburg process (Burnett et al. 1996) should be envisaged. Liming materials are common in some areas of Senegal. The usefulness of these materials depends largely on their chemical characteristics and proximity to acid soils.

References:


