

# Niger

Total population (July 2000 estimate): 10,076,000

Area: 1,267,000 km<sup>2</sup>

Annual population growth rate (2000): 2.75%

Life expectancy at birth (1998): 48.9 years

People not expected to survive to age 40 (1998): 35.2% of total population

GDP per capita (1998): US \$739



Landlocked arid Niger occupies a large expanse of central West Africa at the edge of the Sahara Desert. Northern Niger is occupied by the Air Mountains and extensions of the Hoggar Mountains from Algeria. The Niger River crosses the southwest corner of the country. The climate is hot and dry. More than half of the country receive less than 250 mm precipitation per year. Only in the extreme south, at the border with Nigeria, Benin and Burkina Faso, does the annual rate of precipitation exceed 600 mm.

Niger is one of the poorest countries in the world and droughts and famines are recurrent problems affecting the country. Niger's agriculture is based on livestock rearing and crop production. In 1999, the agricultural sector accounted for 41% of the GDP. Ninety percent of the population lives in rural areas and is engaged in agricultural practices. Population growth and subsequent increased demand for food production creates a strong pressure on the fragile agricultural resources of Niger.

Agriculture consists largely of a subsistence-oriented, rainfed crop production system, combined with livestock rearing and other commercial activities. Low precipitation is the main limiting factor for crop production, although the decline in soil fertility in the sandy acid soils with low organic matter is another. The main soil-limiting nutrients are nitrogen and phosphorus. Food crops are millet, sorghum, cowpeas and cassava. Agricultural exports are mainly livestock, cowpeas and onions.

The main mineral commodities produced in Niger are uranium and gold. The uranium reserves in the north of the country were estimated by the OECD/Nuclear Energy Agency as the fifth largest in the world (OECD/NEA 1980). The combined uranium production in 1999 was 2,916 tonnes (Mining Annual Review 2000). Small amounts of coal are also produced. Recent mineral exploration efforts focus on gold mineralization in the western part of Niger. Small-scale mining of precious minerals employs some 15,000 people (International Labour Organization 1999).

Petroleum exploration resulted in the discovery of a 300 million barrel resource (Mining Annual Review 2000).

### **Geological outline**

Precambrian rocks underlie large parts of Niger but Quaternary and Neogene continental weathering products and sand dunes conceal most of the Precambrian rocks. Paleoproterozoic rocks are exposed in an area to the west of the capital city Niamey. They form a continuation of the Birimian rocks from Burkina Faso (Wright *et al.* 1985; Pons *et al.* 1995). Other Precambrian rocks occur in the Air Massif in the north of the country. Neoproterozoic sequences crop out some 100 km south of Niamey along the border with Benin and Burkina Faso, in a continuation of the Volta Basin.

Paleozoic platform sediments of marine and continental origin occupy parts of northeastern Niger and the Agadez Basin west of the Air Massif. Cretaceous marine and epicontinental sediments of the Ilullemeden Basin occur in the central part of Niger. Tertiary sediments cover parts of the southwest, east of Niamey.

Volcanic activities, with associated lavas, tuffs and ash deposition, have taken place intermittently from the Devonian to the Quaternary.

### **AGROMINERALS**

#### **Phosphates**

Phosphate mineralization has been found in at least three different geological environments in Niger. The best known phosphates are the Eocene phosphorites of Tahoua and the Neoproterozoic phosphorites of Tapoa.

### **The Upper Cretaceous to Eocene phosphorites near Tahoua.**

Phosphate nodules occur in flat-lying upper Cretaceous to Eocene sediments near Tahoua, 375 km northeast of Niamey. Initial geological and geophysical assessments were carried out in valley outcrops east and southeast of the village of I-n-Akker (or Aneker), some 63 km north-northwest of Tahoua (Dumas 1971), and in the Kao area. Initial geological surveys carried out in cooperation with a Canadian company (Watts, Griffis and McQuat) indicate that the phosphates occur as discrete nodules in various layers of Paleocene (or possibly Eocene) argillites - 'La series argileuse.' These phosphate-bearing argillites lie below the Tertiary 'continental Terminal' and rest on Paleocene calcareous sediments (Dumas 1971). The nodules are very fine-grained, hard, cream-coloured, spherical or disc-shaped, break with a conchoidal fracture, and stick to the tongue. Nodule size ranges from less than 1 cm to 'baguette-size,' up to 75 cm length. The  $P_2O_5$  concentration in the nodules ranges from 19-27 % with a mean of 23.7%  $P_2O_5$  (63 samples). Associated minerals in the nodules are limonite and goethite, quartz and kaolinite (Dumas 1971). The clay in which the nodules are embedded is palygorskite (attapulgitite) and the percentage of nodules in the clay matrix varies but is usually less than 4%. The thickness of the shale beds in which the nodules occur in the I-n-Akker area is 6.5 m.

Elevated radioactivity coincides with the nodule-bearing argillite bed. Detailed investigations show however, that the elevated radioactivity is largely confined to the clays and not to the phosphate nodules. The results of chemical analyses of 14 phosphate samples show that the  $U_3O_8$  concentration in the phosphate nodules is less than 100 mg/kg (Dumas 1971).

The total tonnage of the Tahoua phosphate resource, as reported by Johnson (1995), is 7.5 million tonnes phosphate rock (concentrate), grading 32%  $P_2O_5$ . Truong and Montange (1998), quoting *La Chronicle de la Recherche Minière* 484 (1986), BRGM – Orléans, estimated the reserves of Tahoua at 5 million tonnes with an average grade of 25%  $P_2O_5$ .

Hanon (1990) describes another extensive low-grade Upper Cretaceous to Eocene phosphate resource to the south and southeast of Tahoua towards the border with Nigeria. Detailed mapping was carried out by members of a joint Niger-Belgium cooperative project to the south of Tahoua (Hanon 1990). The sediments are gently inclined to the southwest and capped by a ferruginous Upper Eocene formation.

Phosphatic nodules are reported from various stratigraphic horizons within the Upper Cretaceous to Eocene sedimentary sequence. Phosphate nodules in the 'Formation de Farim Doutchi' of upper Cretaceous (Maastrichtian) age are relatively rare (Hanon 1990) but elevated phosphate concentrations are apparent in the upper 'Formation d'In Wagar,' the top bed of the Maastrichtian (Upper Cretaceous). This bed contains bone debris of fishes and reptiles as well as coprolites.

However, the main phosphate nodule horizons occur in the overlying Paleocene and Lower Eocene 'Formation de Garadaoua' where phosphatic nodules reach sizes of 20-50 cm. The phosphate nodules occur in clay-rich horizons with palygorskite (attapulgitite) as main clay mineral. From their very thin-layered appearance these clay beds are also known as 'schistes-carton' or 'schistes papyraces' (Hanon 1990). Weathered out and eroded phosphatic nodules are scattered on valley bottoms. Accumulations of phosphatic nodules of the Paleocene to Lower Eocene occur in the region of Tamaske (35-40 km east-southeast of Tahoua) and at the confluence of the Keita and Ode Rivers (Hanon 1990).

The phosphate-bearing beds north and south of Tahoua can be correlated with phosphate-bearing beds of neighbouring Nigeria and Mali (Hanon 1990) and are part of a large phosphate province that cuts through central West Africa.

The chemical analyses of the phosphates from the Tahoua concentrate (from I-n-Akker) are high in  $P_2O_5$  (27.7%) but also relatively high in  $Fe_2O_3$  (13%) (Bationo 1990; Bationo *et al.* 1998). The iron likely originates from the iron oxides goethite and limonite in the nodules. The crystallographic data of the phosphate provided by Pichot *et al.* (1981) and Roesch and Pichot (1985) suggest that the Tahoua phosphate is a francolite with a relatively low reactivity (unit-cell a-value = 9.351 Å). In contrast, the crystallographic data provided by Mokwunye (1995) indicate a francolite with unit-cell a-value of 9.331 Å and a molar  $PO_4/CO_3$  ratio of 4.88, indicating much higher reactivity. The neutral ammonium citrate (NAC) solubility data range from 1.9-3.6%  $P_2O_5$  illustrating the great variability of the phosphate materials. Truong and Montange (1998) rank the reactivity of Tahoua PR as 'medium.' The surface area of the Tahoua francolites is high, 14.7 m<sup>2</sup> per gram for the 0.5 mm fraction and 19.1 m<sup>2</sup> per gram for the 0.1 mm fraction (Truong and Fayard 1995).

Phosphate nodules from the exposed and weathered shale beds in the I-n-Akker and Kao area north of Tahoua were extracted in the 1970s and 1980s from trenches with shovels and pickaxes and the nodules were hand picked. Approximately 1,000 tonnes of phosphate rock per year were produced from 1979 to 1984 in this very dry and remote area.

The phosphate nodules were transported to Tahoua and milled at a plant with a capacity of 10,000 tonnes per year. Most of the phosphates mined and processed between 1979 and 1984 were used for direct application trials (Van Kauwenbergh *et al.* 1991). Costs of production, including excavation, milling and transport, were US \$66.67 per tonne of phosphate concentrate (Dahoui 1995). With transportation to the farming areas, administrative costs and margins, the total cost of Tahoua phosphate rock (Tahoua PR) was US \$125.71 per tonne (Dahoui 1995).

#### **Agronomic Testing of Tahoua Phosphate Rock**

Scientists from national and international institutions have tested Tahoua PR over many years on various soils, in various agroecological zones, and in various farming systems. Agronomic test work included studies by Roesch and Pichot (1985), Bationo *et al.* (1990, 1998) and Mahamane *et al.* (1997). The results show that Tahoua PR proved 82-91% as effective as single superphosphate (SSP) for millet production on sandy soils in Niger in both the initial and subsequent seasons (Bationo *et al.* 1990). The effectiveness of Tahoua PR proved better in agroecological zones with higher precipitation. Tahoua PR also proved more effective on millet than on cowpea (Mahamane *et al.* 1997; Bationo *et al.* 1998).

As part of a GTZ supported project, a team of agronomists and agro-economists from Niger and Germany carried out detailed economic analyses and agronomic research in Niger (Lamers *et al.* 1999). These researchers concluded that the application of medium quantities of Tahoua PR (39 kg Tahoua PR/ha) in favourable ecological settings seems one of the more promising fertilizer application strategies, along with other measures (Lamers *et al.* 1999).

Agroeconomic evaluations show that the value-to-cost ratio (VCR) of directly applied Tahoua PR is higher than that of SSP. It is interesting to note that the highest yields were not necessarily the most cost effective and beneficial options for the farmer. The highest VCR was reached with Tahoua PR application followed by additional hillside pocket application of 3 kg P per hectare superphosphate (Bationo *et al.* 1998). The profitability of fertilizer applications varied according to rainfall zones and on location specific conditions (Lamers *et al.* 1999).

Scientists from the International Crops Research in the Semi-Arid Tropics (ICRISAT) conducted on-farm evaluations of soil fertility options in Niger. Their work indicates that the most cost-effective technology is Tahoua PR applied on millet-cowpea crop rotation in favourable ecological settings.

### Phosphorites of Possible Upper Cretaceous Age.

Nearly horizontal layers of possible 'Upper Cretaceous' phosphorites have been reported from boreholes at Aschia Tinamou northeast of Zinder and 45 km west-southwest of the Massif de Termet, north of Goure (Greigert and Pougnet 1967). Unfortunately these layers have no surface outcrops and information on extent and grade are very limited. The association of phosphorites with palygorskite (attapulgitic) clays suggests a favourable environment for phosphate accumulations (McClellan and Notholt 1986). The age of these phosphates is not clear.

### Upper Devonian to early Carboniferous phosphorites.

Few details have been reported on the Lower Carboniferous 'gypsiferous phosphate nodules' in the black shales of the Talak Formation in northern Niger, north of Agadez (18° 45' N; 7° 50' E). The Talak Formation overlies the glaciogenic Devonian to early Carboniferous Teragh Sandstone (Hambrey and Kluyver 1981). The phosphates occur within the sequence of black fossiliferous argillites of the Talak Shale Formation, which also contains Lumachelles (*Productus*, *Spinifer*), bryozoans and lingulas (Hambrey and Kluyver 1981). No data on the sedimentology, thickness of the phosphatic beds or composition and mineralogy of these 'gypsiferous phosphates' are provided.

### The Neoproterozoic Tapoa (Parc W) phosphorite deposit.

By far the largest phosphorite resource in West Africa is located at Tapoa, close to the border with Benin (12° 29' N; 2° 25' E) (Figure 2.5). This Neoproterozoic phosphate deposit, approximately 135 km south-southeast of Niamey in the Parc Nationaux du 'W,' also called Parc West, can be geologically correlated with the phosphorite deposits of Kodjari in Burkina Faso and Mekrou Bend in Benin. The phosphatic beds are intercalated with shales and siltstones. The flat-lying, 30-40 m thick sedimentary succession is largely covered by thick sandstones. The grade of the phosphorite sequence ranges from 18-35% P<sub>2</sub>O<sub>5</sub> (Trompette 1986) with reserve estimates ranging from 100-500 million tonnes of phosphorite containing 23% P<sub>2</sub>O<sub>5</sub>. Similarly, Truong and Montange (1998) quoted the estimated reserves of Tapoa at 200 million tonnes with a grade of 23% P<sub>2</sub>O<sub>5</sub>. According to the Mining Annual Review (1995), the phosphate resources are approximately 400 to 500 million tonnes.

Lucas *et al.* (1986) characterized coarse phosphorite samples from Parc West. X-ray diffraction analysis of the apatite indicated a crystallographic unit-cell a-value of 9.354 Å. The refractive index is 1.627. McClellan and Saavedra (1986) determined the a-value of 9.364 Å, with a mean refractive index of 1.624. The agronomic potential based on measurements of the molar PO<sub>4</sub>/CO<sub>3</sub> ratio (15.2) and the mineralogical parameters are indicative of a low carbonate-substituted francolite and thus a phosphate rock with low reactivity. The measured neutral ammonium citrate (NAC) solubility of Parc West PR ranges from 1.4-2.8% P<sub>2</sub>O<sub>5</sub> (Mokwunye 1995), lower than many other sedimentary phosphates. However, the iron and aluminum contents of these rocks are low (2.9% Fe<sub>2</sub>O<sub>3</sub>), making them more suitable for modification techniques like partial acidulation.

Bationo *et al.* (1990) demonstrated the higher efficacy of directly applied finely ground Tahoua PR *vis-à-vis* Parc West PR, reflecting the higher reactivity of Tahoua PR. However, partial acidulation (PAPR), was successful for the iron-poor Parc West PR and less effective for the iron-rich Tahoua PR (Bationo *et al.* 1990). This was consistent with the findings of Hammond *et al.* (1989), who indicated that the Fe<sub>2</sub>O<sub>3</sub> + Al<sub>2</sub>O<sub>3</sub> content of PR can significantly influence the agronomic effectiveness of PAPR.

In general, the agronomic effectiveness of Parc West PR is low when applied directly to the soils due to the inherent mineralogical constraints but can be upgraded by partial acidulation or other modification techniques (Bationo *et al.* 1995).

**Limestone/dolomite**

Large resources of Precambrian marbles occur in remote parts southwest of the Air Massif (Gwosdz 1996). Thin lenses of Precambrian dolomite are reported from an area close to the border with Mali, near Firgoun. Cretaceous limestones occur in several locations in central Niger, specifically east of Tanout (near Damergou), and around Tchi-n-Salantine and southeast of the Air Massif. Paleocene limestones near Malbaza are utilized for the production of cement (Gwosdz 1996).

**Gypsum**

Johnson (1995) reports several gypsum deposits in Niger, the largest of which is at I-n-Aridal with 28 million tonnes. No further information on quantity, quality and extractability of the gypsum deposits and occurrences of Niger are reported.

**Agromineral potential**

Niger's agromineral potential, especially for phosphates, is good. The country is well endowed with large phosphate resources. Nodules with 18-35% P<sub>2</sub>O<sub>5</sub> from the flat lying Paleocene-Eocene sediments in large areas north and south of Tahoua are of good quality and have good potential for direct application.

From a large-scale mining point of view, however, the resource is probably uneconomic. Appropriate small- to medium-scale mining and processing techniques including selective mining, breaking up of the clay-rich matrix and screening with a trommel to concentrate the nodules should be tested. In addition, grinding and pelletizing equipment as well as biological modification techniques should be envisaged to increase the usefulness of these valuable resources for the local market.

The enormous Precambrian-Cambrian resources of relatively unreactive phosphates from the Parc West deposit (Tapoa) have to be evaluated in more detail to determine their potential as modified phosphate fertilizers. The choice of appropriate phosphate modification technologies will largely depend on the market and end use of these resources.

Other agrominerals have only limited potential for enhancing Niger's crop production.

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