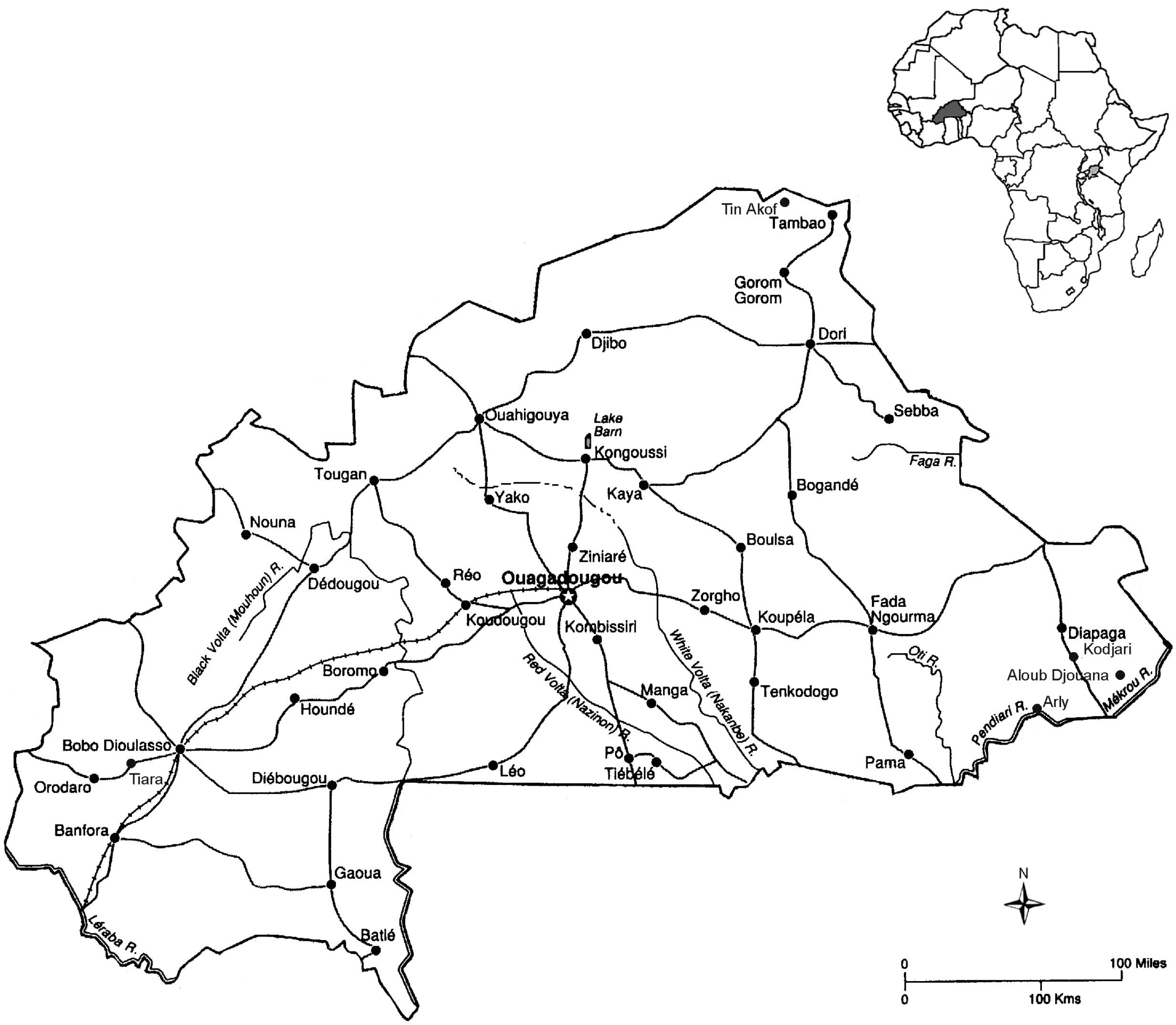
Burkina Faso

Total population (July 2000 estimate): 11,946,000
Area: 274,200 km^2
Annual population growth rate (2000): 2.71%
Life expectancy at birth (1998): 44.7 years
People not expected to survive to age 40 (1998): 39.9% of total population
GDP per capita (1998): US $870



Burkina Faso is a landlocked country south of the Sahara Desert. Much of northern Burkina Faso lies in the Sahel zone at the fringe of the Sahara. The climatic and agroecological zones change from near desert in the north via a central plateau zone into areas of wooded savanna in the south. Annual rainfall increases from less than 200 mm in the north to 1,100 mm in the south of the country.

Burkina Faso's economy is largely founded on agricultural and livestock based production. In 1999, the agricultural sector accounted for 31% of the GDP and provided a livelihood to more than 90% of the population. Crop production is mainly at the subsistence level, but some larger farms cultivate cotton for export. The agro-pastoral land use system is based largely on the production of pearl millet, sorghum, cowpeas and groundnuts.

The main soil productivity constraints on the predominantly sandy acid soils are related to climatic conditions and nitrogen and phosphorus deficiencies (Bationo *et al.* 1998, 1992). Unpredictable rainfall distribution patterns in the north of the country limit the growth of the main cereals, millet and sorghum. In the central plateau zone where millet, sorghum and maize are grown, the pressure on soils is the greatest (Teboh *et al.* 1997). Degradation of soils is largely related to water and wind erosion as well as nutrient removal. Regional soil nutrient balances for the period 1979-1988 show that annual nutrient removal without replacement are approximately 23 kg/ha of N, 5 kg/ha of P_2O_5, and 16 kg/ha of K_2O (Teboh *et al*. 1997).

Mining only accounts for a small amount of Burkina Faso's GDP. The main mineral commodity produced is gold, much of which is extracted by the approximately 60,000-70,000 small-scale gold miners (International Labour Organisation 1999).

Geological outline

Metamorphosed Paleoproterozoic rocks of the Birimian underlie most of Burkina Faso. In the far west of the country Paleoproterozoic rocks dip below continental and marine platform sediments of the Taoudenni Basin, which comprise sediments of Proterozoic to Paleozoic age. In the southeast of the country the Paleoproterozoic rocks are concealed beneath Neoproterozoic to Lower Cambrian rocks of the Volta Basin. These largely unmetamorphosed sediments of the Volta Basin form a continuation of sedimentary sequences in Ghana, Togo, Benin and Niger.

Gold, the main mineral commodity of Burkina Faso is mainly mined from Proterozoic rocks and alluvial/eluvial deposits.

AGROMINERALS

Phosphates

The most important agrominerals of Burkina Faso are the Neoproterozoic phosphate rocks in the extreme southeast of the country close to the borders with Benin and Niger (Figure 2.5). The phosphate deposits were discovered in the early 1970s and described in detail by Lucas *et al.* (1980), Trompette *et al.* (1980), Maurin *et al.* (1989), and Trompette (1989). The sedimentary phosphate rock deposits belong to the Neoproterozoic Pendjari Group of the Volta Basin (Figure 2.5). They are located at Aloub Djouana (12^o 8' N; 1^o45' E), Kodjari (12^o 1' N; 1^o55' E) and Arly (11^o 35' N; 1^o25' E). The age of the deposit is 660 ± 8 million years indicating a Neoproterozoic age (Trompette 1989).

The phosphates were deposited at the southeastern flanks of the West African craton in the passive margin Volta Basin, characterized by epicontinental unmetamorphosed sediments. The succession is increasingly folded and deformed towards the east, at the contact with the Neoproterozoic Pan-African Dahomeyan front. The Kodjari and Arly deposits are part of the flat lying Voltaian sediments, the Aloub Djouana phosphate deposit occurs at the eastern side of the Volta Basin, in a strongly deformed thrust zone.

The approximately 100 m thick Kodjari Formation of the Pendjari Group consists of, from bottom to top: breccia (0.1 m), tillite (0-15 m), dolomitic limestone 0.5 - 3 m (often associated with barite), bedded cherts (25-30 m) and argillaceous siltstones or phosphorites (> 10 m). The association of tillite, limestone (with barite) and 'silexite' (a term used by French writers to denote massive chemically precipitated cherts) are commonly referred to as a 'triad' (Wright *et al.* 1985). The tillite is one of the stratigraphic markers in the Neoproterozoic to Cambrian in West Africa. Neoproterozoic 'triads' are also known from other parts of west Africa, especially in the Taoudenni Basin (Slansky 1986).

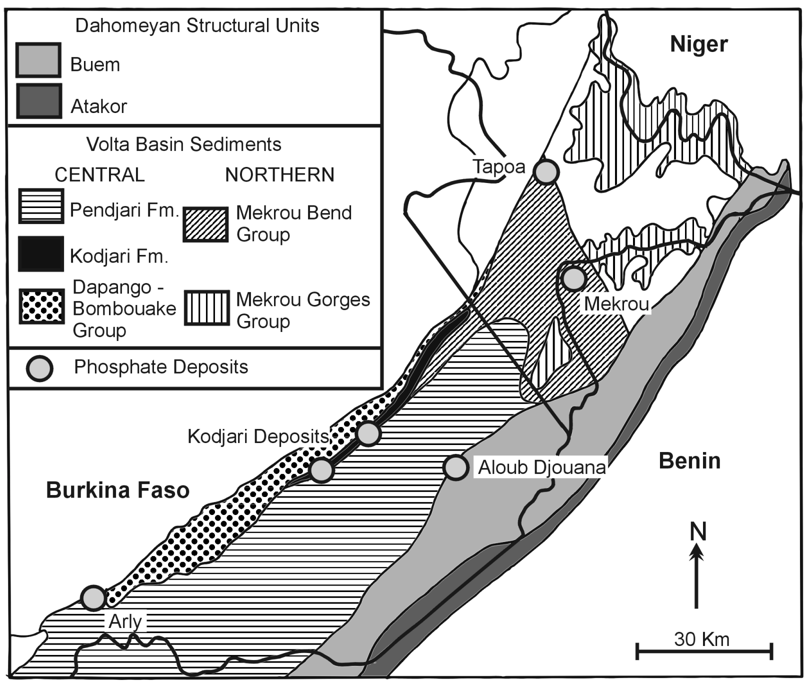


Figure 2.5: Location of Neoproterozoic phosphate deposits in Burkina Faso, Benin and Niger (after Trompette *et al.* 1980).

Detailed mineralogical and chemical characterization of the apatites in the Kodjari and Arly phosphates are described by Lucas *et al.* (1980) and McClellan and Notholt (1986). The apatites of the Kodjari phosphates occur as subrounded grains in a siliceous matrix. The unit cell a-value of the francolite is a = 9.355 Å, (McClellan and Saavedra 1986) and the citrate solubility is 2.3% P_2O_5 (McClellan and Notholt 1986). All chemical and mineralogical data are indicative of a low carbonate-substituted francolite and consequently low reactivity phosphate rock (Kpomblekou and Tabatabai 1994). The trace element analyses of Kodjari phosphate rocks (Kodjari PR) reveal low Cd and As concentrations, <4 mg/kg and <20 mg/kg respectively (McClellan and Notholt 1986).

The lower parts of the 10 m thick, fine grained, well-bedded Kodjari phosphate deposit with micronodules and illite and kaolinite clays were most likely deposited in a low-energy, reduced environment (Lucas *et al.* 1980). The upper parts of the sequence are characterized by more silt and sand size fractions, indicative of increasing energy environments and reworking. Lateritic alteration has resulted in higher Al and Fe concentrations in the upper parts of the deposit (Lucas *et al.* 1980).

The Arly phosphate rock (Arly PR) deposit, located approximately 100 km southwest of Kodjari occurs in a similar stratigraphic position to the phosphates of Kodjari. This phosphate bed, up to 1.5 m thick, is mainly composed of poorly bedded coarse-grained detrital phosphorites with a much higher silicate content than the Kodjari phosphates. Lucas *et al.* (1980) interpreted the coarse-grained Arly phosphorites as reworked phosphates deposited in a high-energy environment.

At the structurally complex Aloub Djouana deposit, east of Kodjari, the phosphatic sandstones are coarse-grained with abundant allochthonous fragments (mainly quartz and feldspars). These phosphatic sandstones are interpreted as sediments formed in turbulent depositional environments with widespread reworking (Trompette *et al.* 1980; Maurin *et al.* 1989).

Agronomic Testing of Kodjari Phosphates

The Kodjari phosphates have been agronomically tested as direct application phosphate fertilizers by nationally and internationally supported agricultural research projects. However, the reactivity of Kodjari PR is low and consequently the yield responses were generally low as well. While maize responded only slightly to Kodjari PR application, cowpea, a legume dependent on vesicular-arbuscular mycorrhizae (VAM) colonization for uptake of sparce soil P, responded more strongly to the application of Kodjari PR (Muleba and Coulibaly 1999). Also, the application of Kodjari PR had significant residual effects in two soils in Burkina Faso for up to two years (Muleba and Coulibaly 1999).

Experiments using modified Kodjari PR were more successful. In combination with organic 'wastes' the PR was more effective than PR alone (Lompo 1993). Also, growth chamber experiments using energy intensive 'mechanically activated' Kodjari PR increased the solubility considerably, resulting in significantly higher yields (Kantor *et al.* 1990, quoted in Hoffmann *et al.* 1991, see chapter Malawi). Research by Kpomblekou and Tabatabai (1994) showed that organic acids could release greater amounts of P from the low reactivity Kodjari PR than from Florida phosphate rock of medium reactivity. It seems that complexation plays a major role in the increased release of P from Kodjari PR.

The reserves of the various phosphate rock (PR) deposits, cited by McClellan and Notholt (1986), are: Aloub Djouana: 224 million tonnes at 15% P_2O_5, Kodjari: 80 million tonnes, and Arly: 4 million tonnes.

Reserve estimates by Trompette *et al.* (1980) are slightly different: Kodjari = 60 million tonnes at 27.5% P_2O_5, Arly = 2.8 million tonnes at 29% P_2O_5. Detailed investigations at Kodjari included drilling at two hills (Hill A and B). Reserves estimates by Maurin *et al.* (1989), and Teboh *et al.* (1997) are: 44 ± 8 and 19 ± 4 million tonnes for Hill A and Hill B respectively at a cut-off grade of 18% P_2O_5. The maximum overburden is 20 m.

So far, only the Kodjari PR deposit has been mined. At Hill A of Kodjari the phosphorites have been extracted from an open pit since 1978. Approximately 20 million tonnes of the Kodjari PR can be extracted after simple removal of the vegetation and the 0.5 m thick soil cover. The reserves at this hill alone are estimated at 44 million tonnes with 25-27% P_2O_5 to a depth of 20 m (Teboh *et al.* 1997). In the late 1990s the Kodjari PR was mined at a rate of 3,000 tonnes per year, using hand-held jackhammers and a loader, The ore was transported to Diapage for crushing and grinding. Some of the phosphates were mixed in compost pits before application.

The ex-factory costs for Kodjari PR were US $65 per tonne. Extraction (mining) with jackhammers and a front-end loader cost US $0.64 per tonne. Transportation from the mine to the grinding mill at Diapaga (42 km away) cost US $5.48 per tonne, and grinding at the plant in Diapaga cost US $42.00 per tonne. The remaining costs were administrative (Teboh *et al.* 1997). A grinding mill with a capacity of 2.5 tonne per hour was used in 1988. It has been operating at less than one-third of its intended capacity due to the relatively small size of the market. A new 5 tonne per hour grinding mill at equipment costs of US$ 1.6 million (!) has been considered (Teboh *et al.* 1997).

Limestone/dolomite/marble

Slightly folded limestones and dolomites occur in northern Burkina Faso close to the border with Mali near Tin Akof with resources of more than 30 million m^3 (Wolff 1996). Precambrian dolomites occur in the west of the country close to Bobo-Dioulasso and Orodara. In some places the dolomites are high in silica and iron and have total reserves in the range of 20 million m^3. Dolomitic marbles with thickness of more than 15 m are reported from Tiara, 32 km west of Bobo-Dioulasa. The decorative marble of Tiara is used for the production of ornamental stone (Wolff 1996). Operations of this kind usually produce considerable ‘wastes’ some of them fine sized materials. Whether any of these liming materials is used for agricultural purposes is not known.

Agromineral potential

The main potential of agromineral development in Burkina Faso lies in the development of the near surface phosphate resources of Kodjari. There are strong agricultural needs for phosphates in the region. Because the Kodjari phosphates are characterized by low reactivity, the agronomic effectiveness as a direct application P fertilizer is low. However, in combination with organic acids and organic wastes (phospho-composting) the Kodjari phosphates show considerable promise (Lompo 1993; Kpomblekou and Tabatabai 1994). Also, early indications show good agronomic response of PR from Burkina Faso on upland rice (Bado and Hien 1998). Modification techniques such as blending and compaction or pelletizing should be tested to improve the reactivity of these locally available phosphate rocks.

At present, the ex-factory price of this phosphate rock is high (US $152.6 per tonne). Reasons for the high price are low rate of production and high costs of energy and imported machinery. In the current situation the import of TSP is more profitable. However, TSP procurement and timely supply is not always secured and small-scale farmers often cannot afford the purchase of imported fertilizers (Teboh *et al.* 1997).

Considering the main constraints of energy and imported machinery, it is strongly recommended to explore possibilities using more labour intensive and alternative technologies with lower energy requirements and capital costs (for instance low-cost adapted crushing and grinding technologies) that are more appropriate and adapted. With the current PR production of less than 1,000 tonnes per year the possibilities of using low-cost small-scale processing techniques should be considered.

Developing low cost phosphate products by combining processed Kodjari PRs with organic matter seems to have good potential (Lompo 1993; Sanchez *et al.* 1997). Transfer and upscaling of successful strategies to increase phosphorus availability from low reactivity phosphate rocks using organic wastes or blending techniques should be encouraged. Plants like rapeseed and local *brassicaceae* that are able to extract P from relatively unreactive phosphate rocks (Weil 2000) should be tested.

References:

Bado VB and V Hien 1998. Efficacité agronomique des phosphates naturels du Burkina Faso sur le riz pluvial en sol ferralitique. Cahiers Agriculture 7:236-238.

Bationo A, Christianson BC, Baethgen WE and AU Mokwunye 1992. A farm-level evaluation of nitrogen and phosphorus fertiliser use and planting density of pearl millet production in Niger. Fert. Res. 31:175-184.

Bationo A, Lompo F and S Koala 1998. Research on nutrient flows and balances in West Africa: state-of-the-art. Agric. Ecosyst. Envir. 71:19-35.

International Labour Organization 1999. Social and labour issues in small-scale mines. TMSSM/1999, 99pp.

Kantor W, Schoenfeld G and E Gock 1990. Improvement of the solubility of rock phosphate by mechanical activation compared to chemical treatments.- Paper presented at IFDC seminar on rock phosphates in Lome, Togo. Quoted in Hoffmann R 1991. Present and potential utilization of agrominerals in Malawi. Techn. Cooperation Proj. 89.2028.2, Malawi-Fed. Rep. Germany, Zomba, 49pp.

Kpomblekou A and MA Tabatabai 1994. Effect of organic acids on release of phosphorus from phosphate rocks. J. Soil Sci. 158:442-453.

Lompo F 1993. Contribution à la valorisation des phosphates naturales du Burkina Faso: Etudes des effets de l'interaction phosphates natureles-materiels organiques. These Doctor Ingenieur. Fac. des Sci. et Techn. de l'Universite National de Côte d'Ivoire, Abidjan.

Lucas J, Prevot L and R Trompette 1980. Petrology, mineralogy and geochemistry of the late Precambrian phosphate deposit of Upper Volta (W Africa). J. Geol. Soc. London, 137:787-792.

Maurin G, Giot D, Sustrac G and E Zoungrana 1989. The Kodjari and Aloub Djouana phosphate deposits, Burkina Faso. In: Notholt AJG, Sheldon RP and DF Davidson (eds.) Phosphate deposits of the world. Vol 2. Phosphate rock resources, Cambridge University Press, Cambridge, UK:219-225.

McClellan GH and FN Saavedra 1986. Proterozoic and Cambrian phosphorites - specialist studies: chemical and mineral characteristics of some Precambrian phosphorites. In: Cook PJ and JH Shergold (eds.) Phosphate deposits of the world, Vol. 1. Proterozoic and Cambrian phosphorites. Cambridge University Press, Cambridge, UK:244-267.

McClellan GH and AJG Notholt 1986. Phosphate deposits of sub-Saharan Africa. In: Mokwunye AU and PLG Vlek (eds.) Management of nitrogen and phosphorus fertilizers in sub-Saharan Africa. Martinus Nijhoff, Dordrecht, Netherlands:173-224.

Muleba N and M Coulibaly 1999. Effects of phosphorus fertilizer sources on cowpea and subsequent cereal productivity in semi-arid West Africa. J. Agric. Sci. 132:45-60.

Sanchez PA, Shepherd KD, Soule MJ, Place FM, Buresh RJ, Izac A-MN, Mokwunye AU, Kwesiga FR, Ndiritu CG and PL Woomer 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh RJ, Sanchez PA and F. Calhoun (eds.). Replenishing soil fertility in Africa. Soil Sci. Soc. Am. Special Publ. 51:1-46.

Slansky M 1986. Proterozoic and Cambrian phosphorites - regional overview: West Africa. In: Cook PJ and JH Shergold (eds.) Phosphate deposits of the world. Vol. 1. Proterozoic and Cambrian phosphorites. Cambridge University Press, Cambridge, UK:108-115.

Teboh JF, Cisse AC, Lompo F and LM Zigani 1997. Phosphate rock initiative: A case study of Burkina Faso. Report to the World Bank, 18pp.

Trompette R, Affaton P, Joulia F and J Marchand 1980. Stratigraphic and structural controls of Late Precambrian phosphate deposits of the northern Volta Basin in Upper Volta, Niger, and Benin, West Africa. Econ. Geol. 75:62-70.

Trompette R 1989. Phosphorites of northern Volta Basin (Burkina Faso, Niger and Benin). In: Notholt AJG, Sheldon RP and DF Davidson (eds.): Phosphate deposits of the world. Vol. 2. Phosphate rock resources, Cambridge University Press, Cambridge, UK:214-218.

Weil RR 2000. Soil and plant influence on crop response to two African phosphate rocks. Agron. J. 92:1167-1175.

Wolff F 1996. Burkina Faso. In: Bosse H-R, Gwosdz W, Lorenz W, Markwich, Roth W and F Wolff (eds.) Limestone and dolomite resources of Africa. Geol. Jb., D, 91-96.

Wright JB, Hastings DA, Jones WB and HR Williams 1985. Geology and mineral resources of West Africa. Allen and Unwin, London, UK, 187pp.