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REVIEW OF SOKOTO PHOSPHATE DEPOSIT SOKOTO, NIGERIA.

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ABSTRACT

The quality of the phosphates from the Sokoto basin is reviewed. Emphasis is placed on their physical, chemical and mineralogical characteristics, and its suitability for industrial applications. The phosphates occur as nodules, pellets, as well as primary phosphatic rocks. They are francolites with quartz as the only crystalline gangue mineral. The P_2O_5 content of the nodules is 36.25 percent by weight, while that of the primary phosphatic rocks range from 5 to 30 percent. Other geochemical determinations indicate that the nodules have acceptable values of the critical ratios, tolerable level of toxic metals, and low values of SiO_2 and organic matter. Reactivity of the phosphate nodules is good as indicated by the high level of carbonate substitution and also meets the quality requirement of commercial phosphates based on its physical characteristic like being moderately hard and can be ground to required particle sizes. The phosphate concentrates are not coarsely textured. The Sokoto phosphate nodules are considered to be similar in quality with those from Togo.

KEY WORDS: Apatite, francolites, nodules, pellets, phosphate.

INTRODUCTION

Phosphates occur as nodules, pellets and primary phosphatic shales and siltstones in the Dange Formation (Paleocene) of Sokoto Basin, Nigeria (Fig. 1).

Nwabufo-Ene (1989, 1990a,b,c,d.) discussed the genesis, distribution, geochemistry, mineralogy and possible end-use pattern for the Sokoto phosphates. The industrial utilization of phosphate rocks have been discussed by several authors, which include (McClellan and Lehr, 1979, Lehr, 1976, Frasier and Lee, 1972). These authors noted that the P_2O_5 content of the phosphate nodules and phosphatic rock is between 35 to 36 percent and 5 to 26 percent respectively.

Other important geochemical parameters that determine the industrial quality of phosphate rocks include the ratio or the following constituents P_2O_5/FO_3(20-26), CaO/P_2O_5(1.30 – 1.64), P_2O_5/MgO (78-80), P_2O_5/F(6-11), $MgFe_2O_3/P_2O_5$ (0.114- 0.115). Also of importance is the organic matter content which must be between zero to 2.8, low content of the toxic metals such as Cd, Cr, V, Se Hg As and Pb, and carbonate- Fluorapatite as the dominant phosphate mineral.

The objective of the paper is to review the Sokoto phosphate deposit with respect to their possible use as raw materials for primary (production) and secondary (manufacturing) industries. The major factors to be considered in this study are physical, chemical, minability and mineralogical characteristics of the phosphate

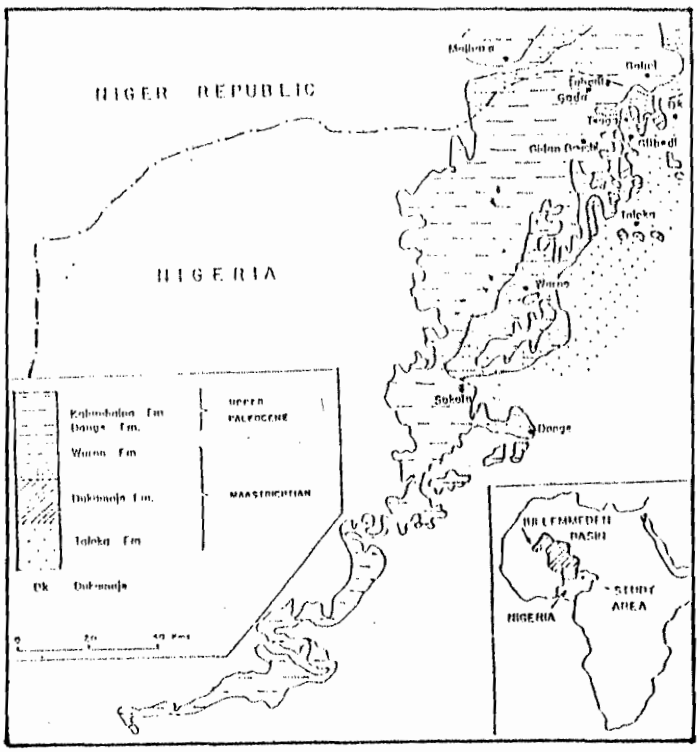

Fig. 1. Outcrop of Marine and Marginal Marine Sediments in South Eastern Jullemmedeh Basin (modified after Petters, 1975).

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rocks. Others are transportation and marketability of the raw and finished products.

GEOLOGY OF SOKOTO BASIN

The Sokoto Basin lies in the northwestern part of Nigeria (Figure 1). About half of the basin is underlain by the Basement Complex, while the remainder is by sedimentary rocks of Cretaceous and Tertiary ages. The Cretaceous sequence commences with the continental Gundumi and Illo Groups, equivalents of the Bima Sandstone (Kogbe, 1976). An intra-Cretaceous unconformity is present in the Sokoto Basin where he Gundumi Group is unconformably overlain by the Maastrichtian Rima Group that is commonly subdivided into three divisions, namely Taloka, Dukamaje and Wurno Formations (Kogbe, 1973). Whereas the Gundumi Formation is overlain only by the Rima Group of Maastrichtian Age, the Illo Formation is overlain successively from east to west by the Rima Group, the Sokoto Group (Paleocene) and the Gwandu Formation (Ecocene – Miocene). In the south of the Wurno town, the Taloka Formation and the Wurno Formation cannot be differentiated because the intermediate Dukamaje Formation thins out. The Taloka and Wurno Formation then narrow appreciably along the Zamfara valley. The Wurno Formation is very similar to Taloka Formation. Their sediments are mainly of estuarine origin. The Dukamaje Formation shows richly fossiliferous marine limestone-shale horizons. There is no evidence in Sokoto of a break in the sedimentary sequence between the Upper Cretaceous and the Lower Tertiary strata. Sedimentation continued in marine and estuarine environments with the deposition of shale, mudstone and limestone.

The Sokoto Group comprises the Dange and Kalambaina Formations and was deposited during the Paleocene. The Gwandu Formation was deposited during the Eocene. The Gwandu Group forms the post-Eocene sediments in the Sokoto Basin. It is a continental sequence of grits and clays that lie unconformably on the older beds. The Gwandu Formation includes locally indurated, interbedded, thick grey, brownish black, red mudstones and fine to very coarse-grained white and brown quartz sand. Individual mudstone sections attain a thickness of more than 60meters while sand sections are less than 35 meters thick.

QUALITY ASSESSMENT OF THE SOKOTO PHOSPHATES PHYSICAL CHARACTERISTICS

The phosphate nodules from Sokoto meet the quality requirement of commercial phosphates based on its physical characteristics like being moderately hard and can be ground to required particle sizes. The nodules do not show evidence of weathering or calcimining. Reactivity of the phosphate nodules is good because of their high level of carbonate substitution.

The phosphate concentrates are not coarsely textured or highly crystalline appetite. Significant variability does not occur and no evidence of replacement or secondary overgrowths. The phosphate shale and siltstone are soft and could easily ground to acceptable liberation size for direct application to soils.

CHEMICAL CHARACTERISTICS

The Sokoto phosphate rocks and nodules have traces of SiO_2 (3.0 – 3.8%) and Na_2O, while mercury (Hg) vary from 0 -2.6 percent and 0-3.6 percent respectively. The ignition of phosphate rocks and nodules varies from 2.90 – 2.99 percent and 1.50-3.50 percent respectively. The moisture content of the phosphate rocks (1.00 percent) is higher than that of nodules. The P_2O_5 content of the nodules is 36.25 percent while that of phosphate rocks range from 10 to 30 percent. Fe_2O_3 content for both phosphate rocks and nodules range from 3.0 – 4.1 percent and 1.1 – 1.2 percent respectively. Other oxides which include ThO_2, U_3O_8, SrO, BaO, MnO, K_2O, U_2O_5, CO_2 for both the phosphate rocks and nodules range from zero to two percent while the CaO content is between 45 and 60 percent. The H_2O content for phosphate rocks (0.25 – 0.40 percent) is higher than that of nodules (0.32–0.35 percent). Other constituents such as U, Pb, Cr, and V generally range from zero to 100 ppm for both phosphate rocks and nodules.

Table 1: The Ratios of Important Chemical Constituents (Nwabufo -Ene, 1990a)

Ratio	Value (present)	Commercial Limit (present)
P_2O_5/R_2O_3	20 – 26	>20
P_2O_5/MgO	78 – 80	>78
P_2O_5/F	06 – 10	06 – 11
CaO/P_2O_5	1.34 – 1.60	1.32 – 1.61
$MgO + Fe_3O + Al_2O_3/P_2O_5$	0.114 - 0.115	0.112– 0.116

The phosphates are carbonate fluor-

apatite (francolite) with the general empirical formula of Ca_{10-1b} Na_a $Mg_b(PO_4)$ 6-XO_4XF_2, where X is the extent of carbonate substitution (Nwabufo-Ene, 1989). Reactivity increases as x increases (McClellan and Lehr, 1979.

The value of x for Sokoto phosphate nodules range from zero t o 1.2 percent (Nwabufo-Ene, 1990a). This is within the level acceptable for commercial phosphates. The only crystalline gangue associated with the phosphate is quartz.

The P_2O_5 content of 36.25 percent and ratios of important constituents for the phosphate nodules indicate that they could be used for most commercial applications. Also significant is the tolerable level of soluble chorine, toxic metals (Cd, Pb, Cr, As, Hg, Se and V) and organic matter.

MINABILITY

The determination of minability factors for phosphates requires a simultaneous consideration of chemical factors (McClellan, 1980). The Sokoto phosphates have acceptable chemical factors when compared with the general high grade limit of chemical composition of phosphates from some phosphate producing countries (Table 2). However, other favourable minable factors are the negligible overburden (Gwandu Formation of Eocene-Miocene Age), expected high annual tonnage, high recovery efficiency, easy exploitation by open cast method and a concentration ratio averaging 2.5 percent nodules in $1m^3$ of phosphate rock (Nwabufo-Ene, 1990c).

The tentative evaluation of reserves in Dilingu and Kasarwasa prospects indicates high grade up to 36 percent of P_2O_5 occurring at 29 million tonnes to a depth of ten meters and 160 million tonnes to a depth of 40 meters. The low to medium grades have 15 -30 percent of P_2O_5, occurring at 800 million tonnes to a depth of 40 meters.

Other prospects at Gidan Bauchi, Gada, Tajaye, Amanawa and Jan Zomo indicates high grade at 100 million tonnes to a depth of 10 meters, and 300 million tonnes to a depth of 40 meters. The low to medium grades occur at 1.5 million tonnes to a depth of 40 meters. These are expected high tonnage's of Sokoto phosphates. The tonnage is acceptable and encouraging.

COMPARISON WITH OTHER WEST AFRICAN PHOSPHATE DEPOSTS.

It is relevant in this study to compare the quality of Sokoto phosphates with those of neighbouring countries (Togo, Niger and Senegal) that have a share of the international phosphate market. Such a study will not only be a guide towards the determination of the local market values, but also its potential in the international market (Table 2).

The results indicate that phosphates from Sokoto are of the same high quality as the Togo phosphates. The values of most of the constituents fall within the high grade limit. The P_2O_5 value of phosphates from Senegal is fairly high, but that of Niger Republic may require beneficiation. The values of SiO_2 for both phosphates from the two countries are beyond the high-grade limit.

The Sokoto phosphate nodules may be suitable for the production of most phosphate fertilizers (Table 3).

Table 2: The percentage comparison of the chemical composition of the phosphates from Sokoto, Togo, Senegal and Niger Republic (McClellan, 1980).

Constituents	Sokoto	Togo	Senegal	NigerRep.	High Grade Limit
Moisture	0.76	0.84	0.63	0.75	0.80
P_2O_5	36.25	36.60	34.00	27.40	32.34
SiO_2	3.44	3.25	8.19	25.70	3.00
Fe_2O_3	1.30	1.20	1.20	3.70	3.00
Al_2O_{3+}	1.50	2.10	2.39	3.00	
F	3.84	3.61	6.44	6.25	4.00
CaO	52.30	52.20	46.10	4750	50.00

Table 3: Most common phosphate fertilizers (Nwabufo-Ene, 1990c)

Materials	P_2O_5 (Weight Percent)
Diammonium Phosphate (DAP)	46 – 53
Monoammonium Phosphate (MAP)	56 – 61
Triple Superphosphate (TSP)	43 – 48
Single Superphosphate (SSP)	16 - 21
Nitrophosphate (NP)	15 – 30
Phosphate Rock (PR)	26 - 31

The nodules are also suitable for the production of phosphoric acid. The phosphoric rocks may be applied directly to soils for crop growing or be used after partial acidulation.

DISCUSSION AND CONCLUSION

The methods employed are indirect and scientific. The indirect method assessed the current demand for phosphate products. The scientific approach was conducted with respect to consumer preference in local and international markets. For the scientific approach, three surveys were covered. The surveys were industrial survey, which studied possible investment in production and development, consumer survey-which included random survey and universal coverage and the trade survey-which studied respondents of various trade outlets.

The importance of the market survey is that it helps in determining the total demand, growth rate, other characteristics and facets of the market through localization of demand, growth of demand in different sectors, consumer preferences, changes in consumer motivations as well as distributive trade practices and preferences.

The consumer surveys were both qualitative. The market surveys were wide and the areas covered include, the nature of product, identification of field horizon, identification of consumers, trade outlets or producers, selection of specific market segments, determination of the size and the design of the random sample analysis of data.

The Sokoto phosphate deposits are not being exploited at the present time despite the great potential. The Superphosphate Company at Kaduna imports phosphates from Togo. The capacity of the plant is 100,000 tonnes a year but it has not exceeded a production level of 60,000 tonnes. Since the phosphate nodules from Sokoto and Togo are of the same high quality, the use of Sokoto phosphate in the Kaduna plant is logically an excellent economic proposition for Nigeria.

Transportation is also a tool in market survey. Transportation problems are important factors in the evaluation of phosphate reserves. The solution to transportation problems has been and will continue to be crucial to the exploitation of phosphates. These include:

(i) Extraction of the ore and movement from mine to concentration plant.

(ii) Transport of concentrate products to conversion plants or transportation terminals.

(iii) Transport of intermediate products to markets or final product conversion sites.

(iv) Transport of inflowing suppliers, plant equipment, fuel, chemicals and related material needs to the various plant sites.

The phosphate deposits in the Sokoto Basin are well connected to a major highway from Sokoto to Gusau. Consequently, the phosphates could be transported to the Superphosphate Factory at Kaduna and elsewhere by rail.

The phosphatic nodules from the Sokoto Basin have physical, chemical and mineralogical characteristics that make them acceptable for use in commercial fertilizer production. They could be used for the production of Superphosphate and phosphoric acid. The quality of the phosphate nodules is suitable for use at the Kaduna Superphosphate Factory. The use of phosphates from Sokoto instead of Togo will bring down the cost of phosphate fertilizer.

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