

משרד האנרגיה והתשתית



REPORT OF GEOLOGICAL
MISSION TO TOGO,
WEST AFRICA

Ron Bogoch

Jerusalem, April 1991

GSI/13/91

MINISTRY OF ENERGY AND INFRASTRUCTURE

GEOLOGICAL SURVEY OF ISRAEL

REPORT OF GEOLOGICAL MISSION TO TOGO, WEST AFRICA

R. Bogoch

Report GSI/13/91

Jerusalem, April 1991

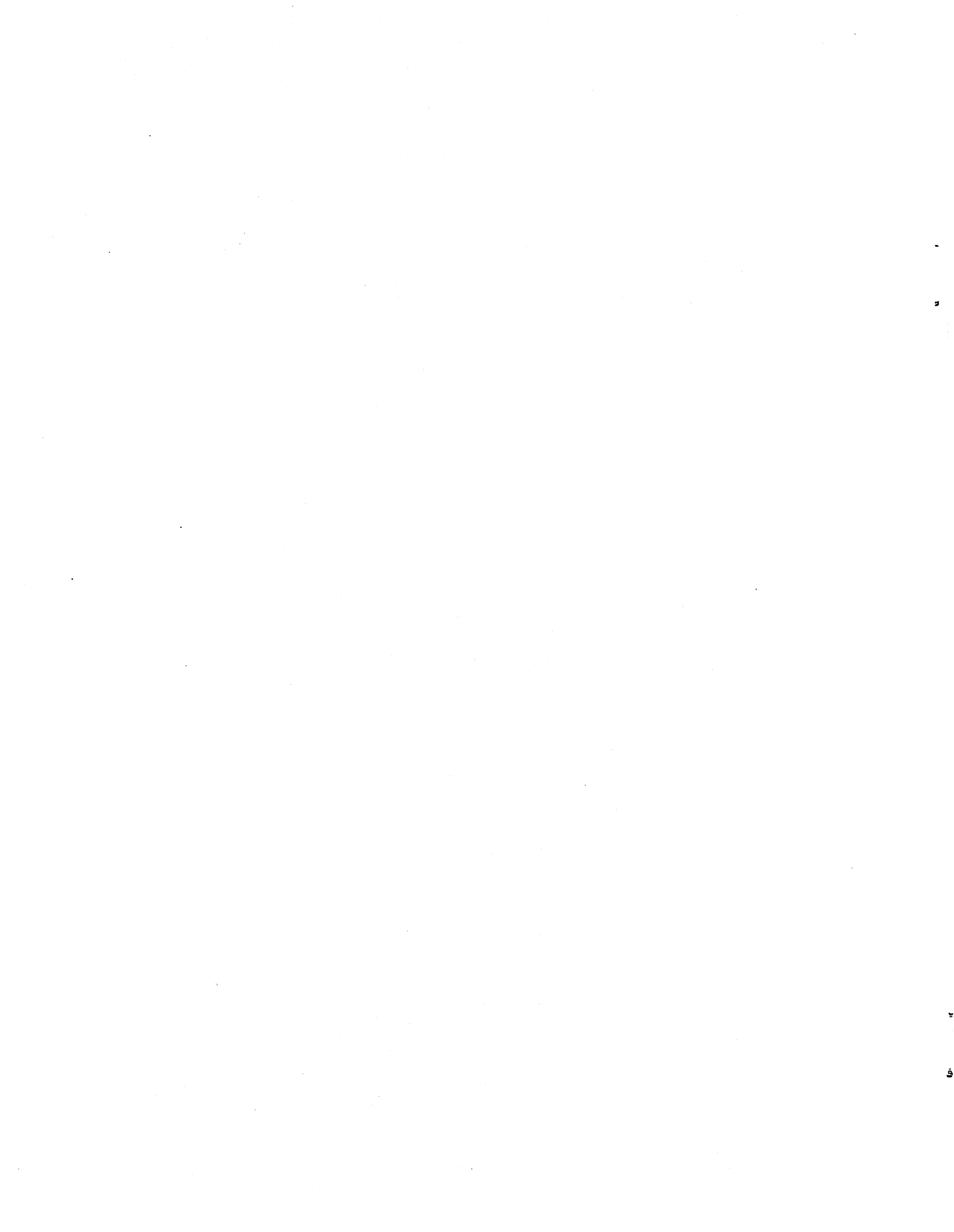


TABLE OF CONTENTS

	Page
ABSTRACT	
INTRODUCTION	1
GEOGRAPHY	2
OUTLINE OF THE GEOLOGY OF TOGO	4
GEOLOGICAL RESEARCH IN TOGO	5
MINERAL RESOURCES OF TOGO	8
Marble	8
Aggregate	8
Phosphate	9
Raw Material for the Cement Industry	9
REGIONAL GEOCHEMICAL EXPLORATION	10
Introduction	10
Methods	11
Results	12
Lome Sheet	12
Platinum-Group and Rare Earth Metals	13
INDUSTRIAL MINERALS	14
Garnet	14
Kyanite	16
Kaolin	18
Attapulgate	19
Quartz Sand	21
Phosphates (Precambrian)	23
Dimension Stone	25
ADVANCED TRAINING PROGRAMS	26
SELECTED TOPICS FOR JOINT GEOLOGICAL RESEARCH	27
RECOMMENDATIONS	28
SUMMARY	31
ACKNOWLEDGEMENTS	32
Figure 1. Location Map	3
Figure 2. Schematic geological map of Togo	6
APPENDIX A. Bibliography of research on the Precambrian phosphorites of Togo	34
APPENDIX B. Location map of described industrial minerals in Togo	36



ABSTRACT

The purpose of the geological mission to Togo was to discuss and examine possible joint projects between the Bureau National de Recherches Minières of Togo (B.N.R.M.) and the Geological Survey of Israel (G.S.I.). Four broad potential areas of cooperation are outlined in this report:

(1) Regional Geochemical Exploration. This is a large-scale project involving stream sediment, alluvium and rock sampling of the Precambrian terrain between the 6th and 7th parallels. It is also suggested that reconnaissance geochemical exploration be carried out in the area underlain by sedimentary rocks (Lome sheet), and specifically for platinum-group and rare earth metals country-wide.

(2) Industrial Mineral Deposits. The nature and potential of seven types of industrial mineral deposits are discussed (garnet, kyanite, kaolin, attapulgite, quartz sand, Precambrian phosphates, dimension stone).

(3) Advanced Training Programs. It is suggested that the Geological Survey of Israel could provide advanced training in the fields of industrial mineral deposits, petrology and mineralogy of clays, analytical geochemistry, library and documentation, and computerized mapping.

(4) Joint Geological Research. A number of possible topics for research involving selected teams from the B.N.R.M. and the G.S.I. are noted.

It would appear to be in the interests of the B.N.R.M. and the G.S.I. to strongly promote joint projects in the field of the economic geology of Togo. It is suggested that small-scale projects should be chosen to initiate the program, rather than attempting to immediately begin with all the possible projects described in this report, in the hope that a small but successful beginning will lead to greater success in attracting the substantial funding required to carry out all the proposals. Each of the recommended industrial mineral projects (quartz sands, attapulgite, and Precambrian phosphorites) is considered to have a reasonable chance of success, i.e., the project (particularly quartz sands) could lead to the establishment of a small-scale industrial mineral industry in Togo.



INTRODUCTION

At the initiative of Mr. N.B. Péré, Director General, Ministry of Mines, Geology and the National Bureau of Mineral Research (Directeur Général des Mines, de la Géologie et du Bureau National de Recherches Minières - B.N.R.M.), and Mr. J. Revah, Ambassador of Israel in Lome, a twenty-one day trip (Jan.-Feb., 1991) was made to Togo to explore the possibility of carrying out a joint Israeli-Togolese project on selected aspects of the mineral resources of Togo.

Guidelines for possible fields of co-operation were based on a preliminary document entitled: "Programme de Travail dans le Cadre de la Cooperation Israel-Togo", prepared by the B.N.R.M. in 1989. This consisted of three proposals: (A) Projet de recherche entre le 9e et 10e paralleles Nord (Feuille KARA); (B) Prospection geochemique strategique entre les 6e et 7e paralleles Nord (Feuille de Lome): socle et basin sedimentaire; (C) Appui technique et formation du personnel du B.N.R.M. More recently, in an agreement signed by the foreign ministers of Togo and Israel in Jerusalem (December, 1990), a geochemical exploration program was recommended as one of several potential joint projects of mutual interest between the two countries.

These general recommendations were clarified in detail during the present visit, and based on discussions with Mr. N.B. Pere and Mr. K.S. Godonou (Director of Research, B.N.R.M.), several specific projects were outlined and are described in this report. These include: (a) an examination of the economic potential of industrial mineral occurrences (Kaolin, attapulgate, quartz sands, garnet, kyanite, Precambrian phosphorites of north-central Togo; (b) geochemical exploration in the Precambrian terrain of southern Togo - Lome Sheet (inventory of metal anomalies based on stream sediment and alluvium sampling); reconnaissance geochemical exploration of mafic-ultramafic complexes for platinum group metals, and preliminary examination of rift-type alkaline intrusives for the rare earth element group metals (based on existing data and samples, as well as preliminary field sampling); (c) advanced training for B.R.N.M. technical staff in Togo and in Israel; (d)

selected topics for joint geological research in Togo. This report also aims to provide an outline of the geology and of the geological research being carried out in Togo.

The geological mission to Togo represents the possible initiation of professional cooperation between the Bureau National de Recherches Minieres (B.N.R.M.) and the Geological Survey of Israel, the initial effort of which will be to bring to fruition the recommendations presented in this report.

GEOGRAPHY

The Republic of Togo is located in West Africa (Fig. 1), extending from the coast of the Gulf of Benin in the south (~6th parallel north) for some 600 km northward to the Burkina Faso border (~11th parallel north). It varies in width between 60 and 120 km, with a total area of 56,000 km². The bordering countries to the east and west are Benin and Ghana respectively.

Most of the country consists of relatively flat to gently rolling plains and river valleys. The main topographic feature is a mountain-plateau chain (maximum elevation ~1000 m) traversing the country from the southwest to the northeast. Other elevated plateaus, and their escarpments, are present to the northwest.

Except along escarpments, outcrops are generally poor, and in many cases, weathered. In flat lying areas, trenching is almost always required to expose fresh rocks. Soils and laterites are abundant, supporting forests, savannah and agricultural growth.

The rainy season in the central and southern parts of the country is generally from July to October, and in the north, from August to October, and during this period, field work is unfeasible.

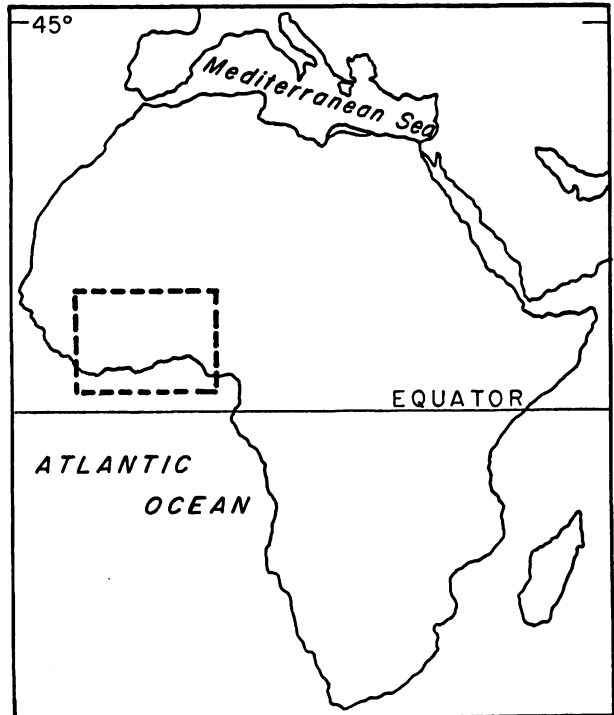


Figure 1. Location map.

OUTLINE OF THE GEOLOGY OF TOGO

The history of geological research in Togo goes back to the early part of this century, and the first geological map (at 1:1,000,000) was prepared in 1910 (Koert, 1910). Geological mapping at 1:50,000 was begun in the 1960's by geologists of the B.N.R.M. The following summary is based mainly on Sylvain et al. (1986).

The Precambrian terrain, which makes up over 90% of the country, forms a series of generally NNE-SSW trending lithotectonic units (Fig. 2). Rocks of the West African Craton (Upper Archaen) are exposed in the northwest and consist of amphibolite and pyroxenite bodies embedded within granitoid gneisses and migmatites. To the S-SW of these, occur the sedimentary rocks of the Volta Basin (Upper Proterozoic), consisting of two major cycles sub-divided by a glacial tillite layer. The lower section, referred to as the "Infratillitique", consists mainly of diverse sandstones, with lesser chert and limestone; the upper "Supratillitique" is composed of limestone, chert, shale, and greywacke at the top. The southwestern part of the Volta Basin sedimentary rocks were metamorphosed during the Pan African orogeny (~600 Ma) and occur as thrust sheets (thrusting from the SSE toward the NNW). Adjacent to (and tectonically overlying) the unmetamorphosed sediments are their weakly metamorphosed equivalents (Buem Transition Zone), and southeast of these is the Atacora Zone, consisting of greenschist to amphibolite facies equivalents of the Volta Basin sedimentary rocks. During the Upper Proterozoic, a proto-rift (axis trending NNE-SSW) developed accompanied by gabbroic and ultramafic intrusions (Kabiye-Sotouboua-Agou complex). The rift was "closed" during the Pan African orogeny, and the metamorphosed equivalents of the mafic intrusions are incorporated within the Atacoran Zone.

Granitic gneisses and migmatites make up the southeastern part of the Precambrian. This southeastern lithotectonic unit is in overthrust contact with the adjacent Atacoran Zone, which also contains tectonically trapped gneisses. The gneiss-migmatite terrain is part of the Benino-Togalese Plain. At least part of these acid gneisses intruded

and were initially metamorphosed during the Eburnian cycle (~2000 to 1600 Ma), whereas others may be related to the Pan African Orogeny (~600 Ma).

The last Precambrian tectonic event, termed the Late Pan-African, resulted in large scale, mainly vertical faulting, and development of mylonitic shear zones, particularly in rocks of the Benino-Togolese Plain.

Marine sedimentary rocks were deposited in the southern part of the country between the Cretaceous (Maastrichtian) and Tertiary. These mainly include weakly indurated clastic sediments (clays and sands) and limestones.

References

- Koert, W., 1910. Geologische Karte von Togo mit Begleitworten. In: H. Mayer (ed.), Das deutsche Kolonialreich, Leipsig, vol. 2, p. 128.
- Sylvain, J.P., Aregba, A., Collart, J. and Godonou, K.S., 1986. Carte géologique du Togo a 1:500,000. B.N.R.M., Mem. 6, 120 p.

GEOLOGICAL RESEARCH IN TOGO

The Direction Générale des Mines de la Géologie et du Bureau National de Recherches Minières (B.N.R.M.) operates out of a main office in Lome, and two small provincial offices in Kara and Atakpame. The professional staff of approximately twenty geologists and geophysicists is supported teams of prospectors (technicians with special training in field methods), drilling crews, laboratory technicians and workers, computer operators, a drafting unit, a documentation unit, drivers and secretarial staff, all totaling some 150 individuals. Analytical facilities include X-ray diffraction, atomic absorption and a recently installed fire assay apparatus.

During the past five years, work by the B.N.R.M. staff has been largely dedicated to the country-wide geochemical exploration program

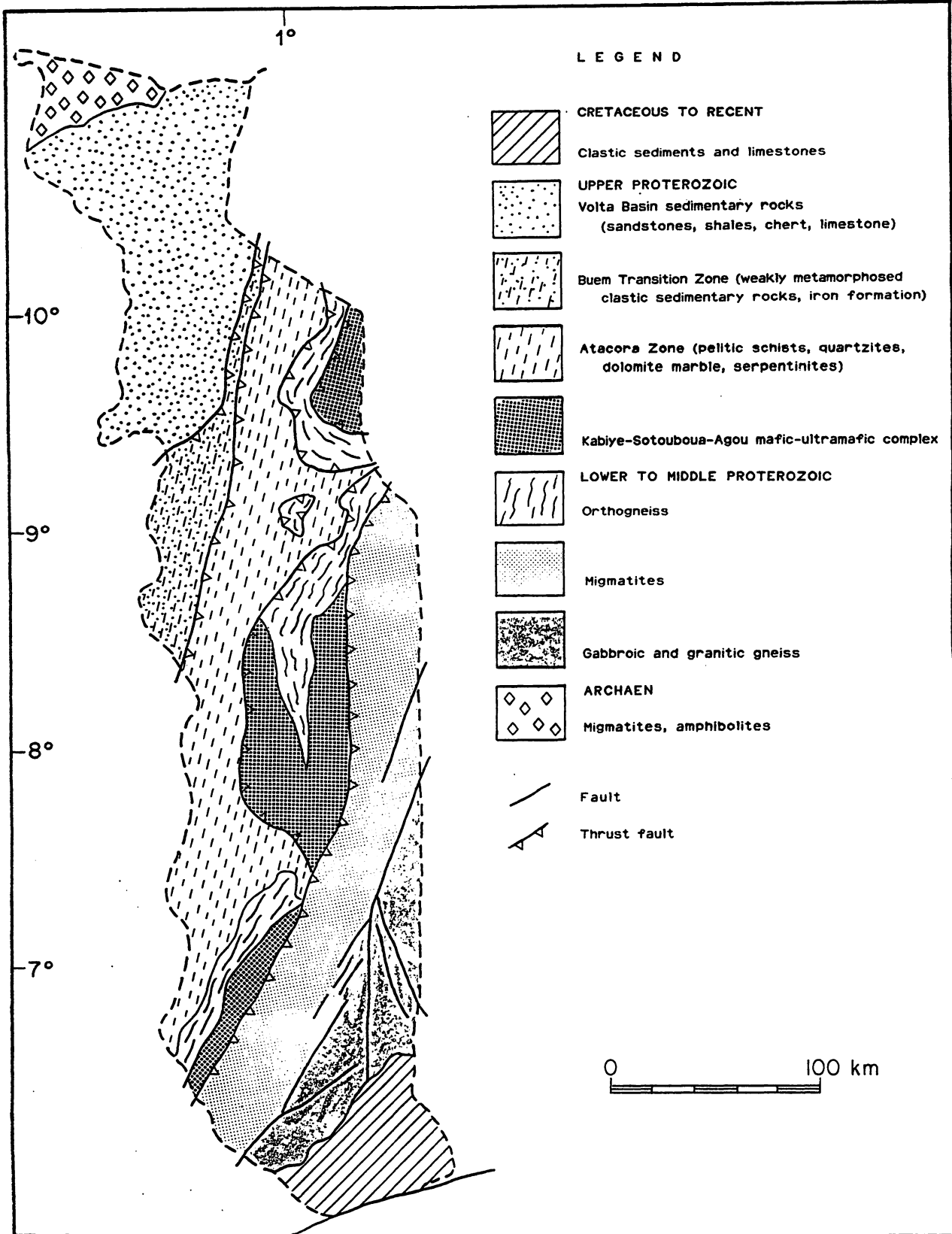


Figure 2. Schematic geological map of Togo (modified after Picot et al., 1990).

("strategic inventory"). This program is being carried out on the basis of the five, 1:200,000 topographic sheets of Togo. The area covered by the three northernmost sheets (between the 8th and 11th parallels) is a contracted project of the Bureau du Recherches Géologiques et Minières (B.R.G.M. Nigeria Ltd.), and that between the 7th and 8th parallels, is a United Nations Development Program (U.N.D.P.) study.

During a five year period ending in 1986, an intensive mapping program was carried out in Togo, whereby geologists from the B.N.R.M. and the B.R.G.M. completed preliminary geological maps of the five 1:200,000 sheets, and a composite 1:500,000 geological map of the entire country. The maps are printed in colour and are accompanied by detailed explanatory notes (B.N.R.M. Memoirs 1 to 6).

Before the initiation of the regional mapping and geochemical exploration projects, and on a limited basis at present, the B.N.R.M. was mainly active in the exploration and detail studies of industrial mineral occurrences. A fairly large data base is thus available on most of the known occurrences of this type.

The University of Benin in Lome has a small Department of Geology within its Faculty of Science. In addition to teaching and geological research, there is an informal cooperation between university geologists and the B.N.R.M. in the recently begun 1:50,000 geological mapping of the country.

There are a number of foreign agencies which operate on a cooperative basis in various geological studies within Togo. The most important of these are the B.R.G.M. and the U.N.D.P. Others have on occasion been involved in specific projects. These include: ORSTOM (Institut Francais de Recherche Scientifique Pour le Développement en Cooperation), a French governmental agency which maintains an office in Lome; the Bundesanstalt fur Geowissenschaften und Rohstoffe (Geological Survey of Germany, Overseas Office), and FRIDA (Fonds de Recherche et d'Investissement pour le Development de l'Afrique). In addition to the U.N.D.P., other United Nations programs have operated in Togo, particularly in the field of hydrological studies.

MINERAL RESOURCES OF TOGO

Mining operations in Togo are limited, and except for the large-scale phosphate deposits in the south, are relatively small scale. A brief description of these works is presented below.

Marble

A marble quarry is located near the village of Pagala, some 450 km north of Lome. It is operated by the Nouvelle SOTOMA company, who also own the marble processing plant in Lome. The quarried rock is one of several large meta-dolomite lenses within the Atacorian (schists) litho-tectonic unit. Three commercial varieties are mined: (1) "clear" - a light greyish white, coarsely crystalline dolomite marble; (2) "melange" - a light grey to beige, coarsely crystalline, linear breccia, dolomite marble; (3) "sombre" - a medium grey to greenish dolomite marble containing hydrous metamorphic minerals.

Quarrying is accomplished by sawing one or two faces of the rock, and close-spaced diamond drilling of the remaining attached faces. If necessary, small explosive charges are used to disengage the blocks, which are then lifted by crane to await transport by truck to the cutting and polishing plant in Lome. Most of the final products are used on the local market, although some export to neighbouring countries has been accomplished, and a few uncut blocks have been shipped to Italy.

A second marble quarry (Gnaoulou) closed some years ago when the remaining marble was apparently too highly fractured for quarrying of large blocks. Other potential sites for dolomite marble are located at Djéti and Fafahoué.

Aggregate

Two relatively large quarries (operated by the INITO Co.) for the production of aggregate are located within approximately 50 km north of

Lome. These produce various sized aggregate from dioritic gneiss. Most of the output is used in road and building construction in the Lome area. Numerous small quarries for aggregate (crushed rock and alluvium) and sand are scattered through other parts of the country relatively close to the cities. Quartzite is quarried locally for use as flagstone.

Phosphate

Togo ranks as one of the top seven phosphate producers in the world. The phosphorites occur in a lower-middle Eocene sedimentary unit (limestone and clays) in the southeastern part of Togo. Two facies of phosphorite are present: the mined ore (which contains some clay), and a calcareous phosphorite, which is being examined for possible future exploitation. The deposit extends for some 35 km in length, interrupted by two, narrow valleys. The maximum width of the clayey-phosphorite is ~2 km, and varies in thickness between 2 and 6 m. Overburden of weakly indurated sands + gravel, and a phosphate-bearing clay, reaches a maximum thickness of 30 m.

The ore consists mainly of fine-grained apatite (150-200 μm), clay, and relatively coarse-grained, phosphate-poor grains. After removing the coarse grains by sieving, and the clay by hydrocyclizing, the concentrate ranges between ~34 and 36% P_2O_5 .

Raw Material for the Cement Industry

A plant for the production of Portland cement has operated in the Lome area for a number of years. Production is sufficient for internal use and for some export to neighbouring countries. At present, all the required raw materials are imported.

Previously, the production of clinker (kilned limestone + clay) was carried out in a large facility in Togo, for which Upper Cretaceous (Maastrichtian) limestone was quarried near the city of Tabligo (~100 km

NE of Lome). The aim of the operation was to provide clinker to the Lome cement plant as well as to other West African countries. Unfortunately, this resulted in over-production, and the clinker plant closed, together with the limestone quarry.

REGIONAL GEOCHEMICAL EXPLORATION

Introduction

A country-wide geochemical exploration program was initiated by the B.N.R.M. in 1985 (Programme de Recherche Geologique et Miniere pour Evaluation du Potential Minier du Togo). The primary aim is to delineate metal anomalies based mainly on stream sediment sampling. For convenience, the field work is being carried out on the basis of 1:50,000 topographic and 1:200,000 geological map sheets.

The project began in 1986, and to date, most of the area between the 8th parallel and the northern border (~11th parallel) have been covered by the joint teams of B.R.G.M. and B.N.R.M. geologists (Picot et al., 1987; 1988; 1989; 1990). Field work, mainly in the area of the mafic-ultramafic rocks (Kabiye zone) in the east of the country, below the 10th parallel, is near completion. The large area containing the un-metamorphosed sedimentary rocks of the Volta Basin is not being sampled by the planned geochemical survey.

The area between the 7th and 8th parallels is being covered by B.N.R.M. and U.N.D.P. teams, and a final report is expected to be issued during 1991.

Based on the available geochemical data, and on information accumulated by the B.N.R.M. in earlier years, there are presently some detailed studies being carried out (B.R.G.M. + B.N.R.M.), such as the geophysical (I.P., S.P., mag.) and diamond drilling program of the "chapeau de fer" (gossans) near Pagala.

Methods

For most of the terrain covered by the B.R.G.M./B.N.R.M. program (north of the 8th parallel), stream sediment samples are taken at a density of 1 sample per square kilometer, except for the Kabiye region (mafic-ultramafic rocks), where a sample density closer to 2/Km² is being targeted. Sampling methods and choice of sample fractions were determined in a preliminary study by Letalenet (1987).

The stream sediment samples are taken at points where streams cross a prepared grid on the 1:50,000 sheets, allowing a certain latitude by the sampling teams according to accessibility. In each case, a few centimeters of the upper layer containing humus is scraped away, and a fine-grained (mainly argillaceous) sample is taken, and sieved at field camps to two fractions: 63-125 μm and <125 μm . The coarser fraction is analysed by I.C.P. (B.R.G.M. laboratory at Oreleans, France) for twenty-four trace elements (Pb, Ag, Zn, Cd, Ba, As, Cr, Cu, Ni, Co, V, Sn, Sb, Bi, W, Li, Be, Y, Nb, La, Ce, Zr, Sr, B) and semi-quantitatively for the major oxides (SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, K₂O, TiO₂, MnO, P₂O₅). The <125 μm fraction is analysed (B.N.R.M. laboratory, Lome) for gold, using aqua regia extraction and A.A. (limit of detection, 20 ppb). Au-analyses are duplicated on some 10 to 20% of the latter samples in the B.R.G.M. laboratory.

In addition to the stream sediment samples, alluvium samples are taken at a density of 1/3km². A pit is dug in stream beds, if possible to bed-rock, and a large alluvium sample taken. If water is available, the sample is "washed" at the sample site in a gold pan, and the heavy fraction retained. Other samples are prepared in a similar manner in the field camp. All samples are then examined in detail for the mineralogical composition (B.R.G.M. lab.).

Rock sampling is carried out sporadically at the discretion of the field geologists, with the aim of testing the different rock types encountered, as well as alteration products.

In the area sampled by the U.N.D.P./B.N.R.M. team (7th to 8th parallels), the sampling density of stream sediments is somewhat higher,

at 2-3/Km². Alluvial and rock samples are taken in a similar manner. For this campaign, all analyses are carried out in the B.N.R.M. laboratories at Lome (mainly chalcophile trace elements and Au).

Results

Stream sediment samples are considered anomalous for a given element when the values are above a total of the mean + 2 standard deviations. Anomalous areas, or zones, are those containing several individual anomalous values. Areas considered to be of particular interest are those which contain anomalous metal values in stream sediment samples together with identified heavy minerals of the same element (or group of elements). To date, several areas of interest have been discovered by the stream sediment/alluvium survey, including such diverse items as gold, nickel, phosphorous and diamonds.

Lome Sheet

An important region not included in the present studies is that of the 1:200,000 Lome Sheet. A strategic geochemical exploration project in this area was originally envisaged as part of the program for Israel-Togo cooperation.

Approximately two thirds of the area is underlain by Precambrian igneous and metamorphic rocks (6,000 km²), the remainder consisting of the Cretaceous and younger rocks of the southeastern Togolese sedimentary basin. The main emphasis on geochemical exploration in the area should clearly be placed on the Precambrian terrain. Sampling and analytical techniques should be similar to those employed in the region above the 7th parallel, to allow a country-wide interpretation and correlation of the data. Based on the geology, it appears appropriate that the sampling density could be varied somewhat, with an aim of 1 sample/Km² in the areas of acid gneisses, and at least 2 samples/Km² in the northwest corner of the area which includes meta-sedimentary rocks, meta-amphibolites and meta-ultramafites.

Although the sedimentary section cannot be considered a primary target, it should not be ignored. Two or three mega-traverses should be made from the base to the top of the section and representative rock samples and alluvium taken for analyses.

Platinum-Group and Rare Earth Metals

Within the framework of the geochemical exploration program being carried out in Togo, analyses for platinum is being made on samples only from the Kabiye zone. However, mafic and ultra-mafic rocks are present throughout the Kabiye-Sotouboua-Agou complex, and should also be examined for platinum-group metals. This can be accomplished in part by analysing selected available samples, and in part be a reconnaissance rock sampling program in the main target areas.

Based on the concept of an ancient proto-rift traversing the country (NE to SW), the presence of alkaline rocks must be considered. If present, they represent possible hosts for the rare earth elements. One approach would be to examine the available geochemical data (La and Ce were routinely measured in all stream sediment samples taken north of the 8th parallel), together with reconnaissance rock sampling in selected areas.

References

- Letalenet, J., 1987. Adaption de la géochimie de type "inventaire" aux conditions physiques du Togo. B.R.G.M. Report 87 TGO 067 DEX. 10 p.
- Picot, J.-C., Letalenet, J., Ouazzane, I., UKoph, K.M. and Ahiagba, K., 1987. Prospection minière stratégique au nord du 10^e parallèle. B.N.R.M./B.R.G.M. Report 87 TGO 196, 79 p. (+ maps, tables).
- Picot, J.-C., Letalenet, J. and Godonou, K.S., 1988. Prospection minière stratégique entre les 8^e et 9^e parallèles. B.N.R.M./B.R.G.M. Report 88 TGO 148, 82 p. (+ maps, tables).
- Picot, J.-C., Aissah, J.C., Coste, B. and Godonou, K.S., 1989. Prospection minière stratégique entre les 8^e et 10^e parallèles.

B.N.R.M./B.R.G.M. Report 89 TGO 165, 69 p. (+ maps, tables).

Picot, J.-C., Aregba, A., Ahiagba, K. and Angel, J.M., 1990. Prospection minière stratégique dans la région de la Kara et des monts Fazao (Togo). B.N.R.M./B.R.G.M. Report R31 326 DEX/DAM 90, 75 p. (+ maps, tables).

INDUSTRIAL MINERALS

Industrial minerals may be defined as any rock or mineral deposit which can be economically exploited, exclusive of metallic ores and fossil fuels. The B.N.R.M. has delineated several industrial mineral occurrences in Togo and these have been examined to various degrees. This section gives a brief definition of the rock or mineral involved, its main uses, a description of the important occurrences, and suggestions for further work (a location map is given in Appendix B).

Garnet

The garnets are a group of metamorphic minerals (silicates with compositional variations in Mg, Ca, Mn, Fe, Cr and Al contents). Their most important properties in terms of industrial mineral use are their high specific gravity and hardness. Almandine ($\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3$) with a specific gravity of ~ 4.25 is the most commonly used abrasive.

The main uses of garnet are (a) high-quality abrasives (glass and ceramics polishing, abrasive coated products, e.g., sandpapers, abrasive wheels, etc.); (b) low-quality abrasives (cleaning and conditioning metals, sandblasting, etc.); (c) part of filter beds; (d) semi-precious gemstones.

Although several occurrences of alluvial garnet are known in Togo, only one of these is considered by Dempster (1967) to have economic potential. This is located near the village of Palokou (Game region), some 20 km north of Atakpame. The garnets derived from the weathering and erosion of garnetiferous quartz-muscovite schists, and chemically

consist mainly of the almandine molecule. The source rock generally contains between 5 and 10% garnet, locally reaching 50%, in crystals from several mm to 1 cm (rarely 2 cm) in diameter.

Three sub-areas of garnet-bearing alluvium were defined (Chollet, 1966): (1) a layer of alluvium along a ridge with a minimum thickness of 50 cm; total estimated garnet content, based on 365 prospection pits is ~100,000 tons; (2) river terrace containing 30-66% garnet, based on 5 pits; and (3) alluvial layer on ridge with 33-55% garnet, based on three pits. The latter two occurrences may contain another 100,000 tons of garnet. Based on a measurement from bulk alluvium samples taken from rivers draining these occurrences, the specific gravity of the garnet averages 3.3-4.0.

The alluvial garnet consists of non-poikilitic crystals, mostly in the range of 3-5 mm diameter. Certain of the coarser crystals contain limonite on micro-fractures.

According to Dempster (1967), the Togolese garnet may have economic potential as an abrasive, or as a substance in wall facings for specific building projects. There has been insufficient work to determine if a certain percentage of the garnet is suitable as a gem. The relatively low apparent specific gravity of the garnets (<4.0 as compared to >4.2 for pure almandine) suggests that it may not be suitable as a high-quality abrasive for an international market.

To evaluate the potential use of the Palokou alluvial garnet deposit, it is suggested that two bulk samples (~20 kg each) be taken in each of the three deposits in the Palokou occurrence. These samples will then be used for the following laboratory tests:

- a. Beneficiation;
- b. Chemistry, mineralogy and crystallography of the garnet;
- c. Hardness;
- d. Resistance to heating;
- e. Petrography (nature of fracturing);
- f. Potential as semi-precious gemstone.

Should the results of these laboratory tests indicate that the

beneficiated garnet is suitable for one or more industrial use, a geological-technical report and a professional marketing pamphlet should be prepared to determine the potential economic interest in developing a small-scale industry based on the garnet deposit. Detailed reserve studies, including numerous prospection pits, would be required if such interest is indicated.

References

- Chollet, R.E., 1966. Rapport de la prospection grènatifère de la région de Lama-Kara. United Nations Special Fund (UNSF), Lome.
- Dempster, A.N., 1967. Rapport sur la prospection pour le grènat au Togo. Report: Fonds Special des Nations-Unis (UNSF) et Direction des Mines et de Géologie du Togo, 18 p., 4 maps.

Kyanite (Disthene)

Kyanite is a high-pressure metamorphic mineral, chemically represented as $Al_2O_3 \cdot SiO_2$. Its main use is in the manufacture of high-alumina refractories (including its conversion by heat to mullite).

Near the village of Yeloun (~70 km north of Atakpame), a kyanite-bearing gneiss forms a low ridge some 20 m high and up to 600 m in length. The most common rock-type in this occurrence is a quartz-feldspar-kyanite+/- sillimanite gneiss, generally containing between 10 and 40% kyanite (Dempster, 1967). Kyanite-pure segregations are also present in boulders along part of the ridge. The gneiss has an estimated thickness of 10 m, and possibly dips at 45° toward the north-east.

Twenty-nine samples were taken from outcrops and trenches, and a composite sample prepared. This was crushed and sieved with the following results (Dempster, 1967):

Table 1. Results of crushing test of Yeloun alluvial garnet occurrence.

Grain Size	% of Sample	% Kyanite
>2 mm	1	95
1-2 mm	12	90
0.5-1 mm	26	75
0.25-0.5 mm	18	30
0.125-0.25 mm	24	20
<0.125 mm	19	10
	Avg.	43%

The crushing/sieving test suggests that beneficiation should not present a major problem.

Assuming an average thickness of 10 m, an average height of the ridge (above the plain) of 20 m, a length of 500 m, a 30% kyanite-content, and a specific gravity of 3.6, the potential reserves of the kyanite are in the order of 1,200,000 tons. Three drill-holes were apparently made during the original prospection, but the results are not available.

The potential use of kyanite in Togo may be problematic due to an apparent lack of an industrial base for the product at present. However, in spite of the relatively small available reserve estimates, a potential overseas market cannot be precluded.

Before carrying out detailed studies of the distribution of the kyanite within the gneiss, and accurate reserve calculation, both of which require drilling, it is recommended that five bulk samples (~10 kg each) be taken from the outcrop for the following laboratory tests:

- a. Beneficiation;
- b. Petrography, mineralogy and crystallography;
- c. Chemical analyses.
- d. Heating tests, refractory tests (conversion to mullite);

Based on the results of these tests, a geological/technical report should be prepared. Assuming positive results, a preliminary market survey should be carried out.

References

Dempster, A.N., 1967. The kyanite occurrence of Yeloun. Report: United Nations Special Fund (UNSF), 7 p., 3 maps.

Kaolin

Industrial clays are generally classified according to end product usage and to their mineral composition. Kaolin, or china clay, is a white, clay-like material approximating the mineral kaolinite (hydrous alumino-silicate). The usage is a function of the method of beneficiation. Thus calcined kaolin is used mainly in the paper, plastic, paint, rubber and catalyst industries; the largest use of water-washed kaolin is as paper coating and filling; air-floated kaolin is largely used for the fibre-glass, paper and plastic industries; most of the unprocessed kaolin is used in the production of refractories and ceramics). The wide range of uses for kaolin are the result of its unique properties as an industrial mineral: chemically inert over a relatively wide range of pH; white colour; good hiding or covering properties when used as pigment; soft and non-abrasive; low conductivity of heat and electricity; relatively low cost.

Kaolinite is present in numerous locations within the Precambrian terrain of Togo, formed as a weathering/alteration product of various magmatic and metamorphic rocks. Three occurrences (all near the city of Kpalime) have been examined by geologists of the B.N.R.M. in some detail:

(1) Lidjoblibo. The kaolin in this area formed as an alteration product of pelitic schists. Overburden consists of 0-3 m laterite. A total of 68 pits and one trench were made for sampling and reserve estimations which indicated the presence of some 3,000,000 m³. Technical tests were positive.

(2) Kpodji. The kaolin deposit is an alteration product of meta-granite. The overburden (0-3 m) consists of soil and laterite. Based on a

chemical analysis, the clay is "kaolinite-rich", and technical tests were positive (average specific gravity = 2.613). Based on 135 pits, the reserves were estimated at 3,500,000 tons.

(3) Nyitoe. The country rock is a mafic gneiss. A total of 79 pits were dug, and reserves of kaolin were estimated at 1,400,000 m³.

The primary aim in the possible exploitation of kaolin in Togo is its introduction into existing local industries, and, if possible, to attempt to initiate new, small-scale kaolin-based industries. It is thus necessary to carry out laboratory- and industrial-scale experiments on the clays from each of the three potential deposits.

a. Laboratory Tests: two representative ~10 kg samples from each of the three occurrences for mineralogical, crystallinity, colour, chemical, physical and ceramic tests. The results of these data will indicate the quality and possible end uses of the ore.

(2) Industrial Tests: Based on the results of the laboratory studies, the kaolin deposit which offers the best potential for industrial use(s) will be sampled on a large scale for shipment and testing in the appropriate plant in Israel.

References

Kpalime, S., 1981. Etude des trois gîtes d'argiles kaoloniques et kaolin du Togo. BNRM Report., 110 p., maps.

Attapulgate

The general term used for clay with strong absorbing, decolourizing and purifying properties is fullers earth. Attapulgate (mineralogically = palygorskite) is a fullers earth-type clay which has applications in the absorbent and gelling and/or thickening fields. Its thixotropic properties provide important thickening and viscosity controls necessary for suspending solids. Mineral thickeners are used in paints, saltwater

drilling muds, and joint compound cements. The most important use of attapulgite is as an absorbent.

Several occurrences of attapulgite are present in the basal Eocene sedimentary rocks of southeastern Togo, spatially associated with the phosphorite deposits. They are considered to have formed as an alteration of sedimentary bentonitic clays. Two such occurrences have been prospected in some detail (Tchota, 1990). The first, approximately 1.5 km NE of the phosphorite deposit, was examined over a surface area of 12 km². It consists of an attapulgite layer, with an average thickness of 8 m. The overburden (average 4 m) consists of sand and soil. The second occurrence is similar.

Based on 40 drill-holes (137 mm core) to a depth of up to 20 m, the possible reserves of attapulgite are 150,000,000 tons. B.M., %CaCO₃ and water content were measured on 32 core samples representing six drill-holes. The results of these analyses for samples of one representative drill-hole is presented in Table 2.

Table 2. Test results of representative attapulgite samples.

Depth Interval	B.M. mg/g	% CaCO ₃	Water Content %
4.0-6.0	120	3.1	18.54
6.0-9.0	97	3.1	16.05
10.4-12.0	120	6.2	18.95
12.0-13.0	93	6.2	36.09
13.0-17.0	82	3.1	11.77
Average	98	3.8	

Both the reserves and apparent quality of the attapulgite as an absorbant warrant further work. It is recommended that the following be carried out:

- a. Four bulk representative samples (~% kg each) should be taken from the main occurrence and examined in the laboratory for beneficiation,

mineralogical, chemical, petrographical (S.E.M.), bulk density and absorption tests;

(2) Should the results be positive, a large, semi-industrial scale sample must be taken and tested.

Reference

Tchota, K., 1990. Prospection détaillée des attapulgites et smectites de Dagbati Watchidome. BNRM Report, 14 p., maps.

Quartz Sand

Quartz sands are used in the production of glass, foundry material, ceramics, abrasives and filters. Their specific use is a function of the amount and nature of impurities, grain size, industrial base in the area, and market availability.

Associated with the argillaceous and carbonate units in the Lower Eocene of south-eastern Togo are several occurrences of quartz sands, two of which have been examined. Both are less than 20 km north of Lome.

The Agoenyive occurrence consists of two layers, apparently separated by argillaceous material, totalling 2 to 4 m in thickness, with the following composition:

Table 3. Chemical composition of Agoenyive quartz sands.

	Upper Layer	Lower Layer
SiO ₂	96.62	97.57
Al ₂ O ₃	1.21	0.85
Fe ₂ O ₃	0.64	0.42
CaO+MgO	0.15	0.15
LOI	0.87	0.43
Sum	99.49	99.42

At the Aveta-Yagon occurrence, 29 pits were dug, and assuming an average thickness of 2 m, a total possible reserves of 2,250,000 tons of quartz sands was estimated. An average of the analysed samples is given in Table 4.

Table 4. Chemical composition of Aveta-Yagon quartz sands.

SiO ₂	98.13
Fe ₂ O ₃	0.11
Al ₂ O ₃	0.76
MgO	ND
Na ₂ O	0.05
K ₂ O	0.04
SO ₃	ND
Cl	ND
TiO ₂	0.28
P ₂ O ₅	0.05
LOI	0.31

At present, all of the bottle and pane glass used in Togo is imported. This suggests that there may be economic potential in the establishment of a glass industry. The following studies are recommended:

- (1) Statistical summary of the quantity and nature of bottled and pane glass imports to Togo on a yearly basis during the past ten years;
- (2) Should this data indicate the possibility of glass production in Togo, geological and technical studies must be carried out on the quartz sand occurrences. These include:
 - a. Sampling of the Aveta-Yagon occurrence: ten representative samples of ~10 kg each.
 - b. Petrographical, mineralogical (including nature of impurities), chemical, granulometric (including AFS) analyses of the samples;
 - c. Laboratory-level beneficiation tests;
 - d. Assuming positive results (with a minimum level being the potential use as bottle glass), large, semi-industrial samples should be taken,

and beneficiated and tested in the Israeli glass industry;

e. Preparation of geological/technical report;

f. Preparation of marketing/investment pamphlet.

References

- Dempster, A.N., 1967. Matériaux de construction et autres substances utiles au Togo. BNRM-UNSF report.
- Lormand, J., 1975. La commercialisation des minerais et matériaux du Togo. Vol. I, 71 p., Vol. II, 190 p.

Phosphates (Precambrian)

Sedimentary phosphorite deposits form as a result of the accumulation of one or more of the apatite-group minerals (P_2O_5 -enriched) from organic sources. Over 90% of mined phosphorite is consumed by the fertilizer industry.

Phosphorite in the Precambrian terrain of north-central Togo was discovered in 1985 (Blot, 1985). Numerous studies have since been carried out by researchers from several national and international agencies (a bibliography is presented in Appendix A). These extensive works involved photogeological and field mapping, surface, pit and trench sampling, geochemical analyses, petrographical and mineralogical studies, 13 drill-holes, reserve calculations, and industrial tests. The report by Pascal and Aregba (1988) summarizes the available data.

The phosphorite occurrences are approximately centered by the village of Bassar (Kara Province), some 450 km north of Lome. They are termed Bassar I to IV, based on the chronological order of their discoveries. The bulk of the geological studies have been carried out on the Bassar I occurrence.

The Bassar phosphorites occur within the Kande litho-tectonic unit (pelitic schists and meta-sandstones; occurring along the western border

of the Atacora Zone) which is considered to be the metamorphosed (greenschist facies) equivalent of the "supratillitique" Volta Basin clastic sedimentary rocks (Sylvain et al., 1986). The unit extends for some 270 km from the border with Benin in the north, to the Badou area in the south, and varies in width (~E-W) from 15 to 25 km. Possible equivalents of the phosphorites in Togo occur within weakly metamorphosed (Buem transition zone) or non-metamorphosed Volta Basin clastic rocks of Benin, Niger and Burkina-Faso (Lucas and Prevot, 1981).

The phosphorite at Bassar I consists essentially of a linear, steeply-dipping layer, discontinuously exposed over 4,600 m in length and varying from 10 to 20 m in width. Towards the north it forms low ridges, and two or more layers are present. The country rocks are quartz-mica schists. The Bassar II occurrence is similar; the exposures at Bassar III consist of several, relatively thin layers; Bassar IV appears to consist of wide bands, but relatively little work has been carried out in this area. The phosphorites were found as far south as Pagala, but these consists of cm-thick, highly tectonized layers.

The phosphorite is strongly indurated, and fairly massive, although micro- and probably meso-folds are present (Castaing, 1987). Reserves in Bassar I and Bassar II were estimated at 1,500,000 tons each. Except for Bassar II, which averages 23% P_2O_5 , the other occurrences contain >34% P_2O_5 , <10% SiO_2 , and <3.2% Fe+Al. In all occurrences, the cadmium and arsenic contents are each <10 ppm.

Further detailed studies are required at Bassar IV. However, there appears little likelihood that the total potential reserves will allow consideration of major exploitation of the Precambrian phosphorites. A reconnaissance regional exploration program with the aim of locating further phosphorite bodies within the Kande and Buem lithotectonic units should be carried out.

Because of the high P_2O_5 and extremely low trace element contents, a small-scale specialized phosphate industry may be envisaged for the Bassar deposits. In addition, production for local use in the future must be considered.

References

- Blot, A., 1985. Un nouvel indice de phosphates dans le centre du Togo: Bassar-Tchatchaminade. Orstom Reports 28, 5 p. and 28b, 7 p.
- Castaing, C., 1987. Etude structurale des phosphates de Bassar (Togo). BRGM Report 127/GEE, 17 p.
- Lucas, J. and Prevot, L., 1981. Caractères petrographiques et microchimiques des phosphatites précambriennes de bassin des Volta (Afrique de l'ouest). Bull. Soc. Geol. Fr., serie 7, vol. 23, pp. 515-524.
- Pascal, M. and Aregba, A., 1988. Etude géologique et minière des phosphates precambriennes de la region de Bassar - Togo (Campagne 1987). BRGM Report 88 TGO 003, 117 p.
- Sylvain, J.P., Aregba, A., Assih-Edeou, P., Castaing, C., Chevremont, P., Collart, J., Monciardini, C., Marteau, P., Ouassane, I. and Tchota, K., 1986. Notice explicative de la carte géologique à 1,200,000, feuille Lome. B.N.R.M., Mem. 5, 64 p.

Dimension Stone

At present, the Pegala marble quarry operated by the Nouvelle SOTOMA company, is the only producer of dimension stone in Togo. This company, together with the B.N.R.M., are interested in developing other sites. Preliminary geological surveys have been carried out at other marble occurrences. There may also be some market potential for the red to pink granite occurrence north of Dapaong (as well as other igneous and metamorphic rocks), and for certain fossiliferous limestones from the sedimentary section in the southern part of the country. In addition, there is a nascent flagstone industry (using meta-quartzite), and possibly some potential for curb-stone and facing stone.

Before any investment in geological research, it is necessary to conduct at least a preliminary market feasibility study for any of these potential products.

ADVANCED TRAINING PROGRAMS

There are a number of fields in which the Geological Survey of Israel (G.S.I.) may be able to provide advanced training for Bureau National de Recherches Minieres (B.N.R.M.) staff. The following suggested programs would be carried out in Israel or Togo.

(1) Industrial Mineral Deposits

Israel has a relatively well developed industrial minerals industry, including a wide range of material for the construction industry, phosphates, Dead Sea minerals, kaolin, flint clay, "bentonite", glass sands, etc. A trip to Israel by B.N.R.M. geologists during which the geological, mining, preliminary and secondary processing, manufacturing, and marketing aspects of the industrial minerals would be studied, would enhance the promotion of similar occurrences in Togo.

(2) Petrology and Mineralogy of Clays

A considerable expertise has been developed by GSI staff in clay research. Since clay deposits in Togo are being targeted for future development, it is incumbent on B.N.R.M. researchers to be able to apply modern analytical techniques for determination of clay mineralogy, crystallography, petrography and geochemistry. In this case, a program could be developed whereby part of the training would be in Togo, and part in Israel at the G.S.I. laboratories.

(3) Analytical Geochemistry

Analytical equipment at the G.S.I. includes atomic absorption, induced coupled plasma spectrography, X-ray diffraction, differential thermal analysis/thermo gravimetric analysis, UV visible spectrophotometer, ion chromatograph, scanning electron microscope with attached energy dispersive and wavelength dispersive analysers, and other routine instruments.

(4) Library and Documentation

At present, the library facilities at the B.N.R.M. are essentially limited to internal reports. Although funding is always of extreme importance in developing a geological library, the G.S.I., using a relatively limited budget, has developed into an important regional documentation center as well as providing the necessary amenities to assist the staff in carrying out modern research. It is highly conceivable that a short visit to Togo by the library and publishing experts at the G.S.I. followed by a return visit to Israel, would help in greatly enhancing the library potential of the B.N.R.M.

(5) Computerized Mapping

The Geological Survey of Israel has recently developed computerized techniques for geological mapping. The following functions are now incorporated into the programs: introduction of data via scanning and digitization; presentation of maps on the screen; printing of maps; interactive processing of maps; transfer of data from air photos to a co-ordinate based map; general processing of geological data; specific processing of data for different requirements. This system would be of considerable value for the B.N.R.M. in allowing the incorporation of new geological data into available maps and assist in the preparation of structural, geological, land use, etc. maps, at different scales as required.

SELECTED TOPICS FOR JOINT GEOLOGICAL RESEARCH

The primary directive of the B.N.R.M. is to carry out mineral exploration. However, an involvement in geological research should also be incumbent upon them. This would certainly enhance the ability of the professional staff to apply new concepts to exploration, would bring the main body of the Togolese geological community into contact and exchange relationships with a large number of foreign geologists, and would hopefully lead to an international reputation for the B.N.R.M. The potential fields for geological research in Togo are almost unlimited.

RECOMMENDATIONS

The various programs outlined in this report may be grouped into four categories: (1) industrial minerals; (2) regional geochemical exploration; (3) advanced training programs; (4) selected topics for joint geological research. Inasmuch as the implementation of these programs is largely dependant on outside funding, it is suggested that the joint programs be started on a limited basis. The initial programs should be chosen so that there is a reasonable chance of success, and which, on completion, will lead to larger scale-funding, which will permit carrying-out of the entire program.

The following recommendations attempt to take these factors into account, and and as such, discuss only those programs which are considered to have economic potential (selected industrial minerals) or which may result in a positive response from funding agencies because of the assistance they are likely to yield for the B.N.R.M.

A. Industrial Minerals

Introduction

Unlike the metals or fossil fuels, where production is dependant solely on prices, industrial minerals are more complex to develop. In most cases, the unit price of a specific commodity is relatively low, so that transportation costs play a significant role in determining market potential. This is particularly true for the international market. Therefore, one of the first factors that should be determined in attempting to develop an industrial mineral deposit, is the potential of the local market. This market potential is almost always a function of the level of industrial development of any particular country, and at present, Togo may be considered as being in the early stages of industrial development, and local markets are thus limited. On the basis of this reasoning, the first item recommended for possible development is the glass industry.

The second important factor to be considered for industrial minerals is marketing. Professional and inovative marketing can frequently determine the economic success of several commodities. Since one prominent example of this is in the use of certain clays as absorbents in the care of household pets, the attapulgite deposits in southern Togo are also recommended for consideration in the initial joint program. The unique properties of the Precambtriaan phosphorites, also lend themselves for consideration due to similar reasoning.

Quartz Sands

The following data suggests that a joint Togolese-Israeli research program on the quartz sands could lead to the development of (initially) a small-scale glass industry in Togo: (a) all of the bottle and pane glass used in Togo is imported; (b) there is a relatively large-scale glass bottling industry in Togo; (c) the sands are located within 20 km of Lome; (d) the preliminary chemical analyses of the sands indicate that they may be suitable, at least for bottle glass.

It is thus recommended that a detailed research and marketing study be carried out for developing a bottle, and possibly pane glass, industry in Togo. An outline for this is presented on the quartz sand section above.

Attapulгите

Attapulгите is an attractive commodity for consideration because of (a) its apparent high quality as an absorbent; (b) location of the deposits close to Lome; (c) large portential reserves.

Although further geological and technical studies are still required (see page xx), the initial work on this project should begin with a potential market study, which should include details such as packaging.

Precambrian Phosphates

The apparent high quality of the Precambrian phosphorite in Bassar area of northern Togo should also be considered in the framework of the initial project. Problems related to these deposits are the presently limited reserves and the distant location from Lome (~450 km). Although further exploration for further occurrences (thereby hopefully increasing potential tonnage) is certainly warranted, this should be considered at a later stage of research, which should also involve consideration of a small-scale industry (perhaps direct usage) for local agriculture.

However, a second line-of-thought may be considered for developing the Bassar phosphorites, and this requires some positive imagination. It appears that natural farm products (organic farming, etc.) is rapidly becoming an important economic factor in European and North American consumption. The Bassar phosphorites, because of their apparently extremely low trace element contents, could possibly be developed as a marketable product either for home gardens (small-scale packaging, high-level promotion), or possibly for limited specialty industrial farming. It is therefore recommended that the Bassar I phosphorite occurrence should be characterized in considerable detail for its mineralogical and geochemical composition, in conjunction with a preliminary market/promotion feasibility study.

B. Advanced Training Programs

Five fields of advanced training for Bureau National de Recherches Minières (B.N.R.M.) staff are suggested: (1) working visits to industrial mineral deposits in Israel; (2) studies of petrology and mineralogy of clays - laboratory studies in Israel and Togo; (3) methods in analytical geochemistry based on the equipment in the G.S.I, laboratories in Israel; (4) assistance in the development of library and documentation facilities at the B.N.R.M; (5) computerized mapping.

It is recommended that the implementation of one or more of these suggested programs be tied into an ongoing joint Togolese-Israeli first stage project.

C. Selected Topics for Joint Geological Research

This is essentially an unlimited field. There has been considerable interest among G.S.I. geologists in the possibility of carrying out research in Togo. This recommended joint research program first requires an agreement in principle by the directors on the B.N.R.M. and the G.S.I., followed by a "matching-up" of potential research partners. Among subjects that could be considered (excluding the applied projects described in this text) are a micropaleontological study of the sedimentary section in southeasterly Togo, selected geochronological studies, sedimentology of the Volta Basin sandstones, etc.

SUMMARY

It would appear to be in the interests of the B.N.R.M. and the G.S.I. to strongly promote joint projects in the field of the economic geology of Togo. The above recommendations are submitted for consideration. The choice of specific, small-scale projects to initiate the program, rather than attempting to immediately begin with all the possible projects described in this report, is made in the hope that a small but successful beginning will lead to greater success in attracting the substantial funding required to carry out all the proposals. Each of the chosen industrial mineral projects (quartz sands, attapulgite, and Precambrian phosphorites) is considered to have a reasonable chance of success, i.e., the project (particularly quartz sands) could lead to the establishment of a small-scale industrial mineral industry in Togo. On this basis, applications should be made to recognized international agencies for funding. It is estimated that costs would not exceed 5 20,000 (U.S.) for each project.

ACKNOWLEDGEMENTS

The visit to Togo included meetings with colleagues whose co-operation is most appreciated. I would foremost like to thank Mr. N.Z. Pere, Director General of the Ministry of Mines, Geology and the National Office of Mineral Research, for providing the facilities required at the B.N.R.M., and for his guidance during the course of the visit. Mr. K.S. Godonou, Director of Research, B.N.R.M., was my guide during the field trip, and spent numerous hours in discussing the many aspects of the proposed program of cooperation. I thank him as well for his kind hospitality.

I had the pleasure of meetings and discussions with several geologists at the B.N.R.M., and would like to thank Mr. A.A. Agbozouhoue, Assistant Director, B.N.R.M., Mr. I. Ouassane, Laboratory Director, Mr. A.P. Aregba, Head of the B.N.R.M office in Kara, Mr. K. Tchota, Head of the B.N.R.M. office in Tsevie, Mr. T. Agbodjan-Prince, and Mr. S.E. Nimon.

I thank Mr. A.D. Ekue, Industrial Director of the Office Togolais des Phosphates (OTP) for allowing me to visit the phosphate deposits and introducing me to the operations, and Dr. K. Afantchawo, for guiding me in the field.

Mr. P. Delange, BRGM representative for Togo and Benin, and Mr. N. Mikhailov, Head of the UNDF Geochemical Survey Project in Togo, both kindly explained their operational methods. Mr. J.-C. Picot, Head of the BRGM field teams, discussed several aspects of the field work.

I thank Mr. K. Pekensi, Director General of Nouvelle SOTOMA, for allowing me to visit the SOTOMA marble processing plant and for guiding me through all aspects of their operations.

Dr. J.-C. Drouet kindly hosted me at the Department of Geology, University of Benin.

I thank Mr. A. Yacoubou, councillor of the Embassy of Togo in Tel Aviv for his useful advise in the preparations for the trip.

I am grateful to Mr. J. Revah, the Ambassador of Israel in Lome, who helped to arrange the trip and was extremely helpful during my stay in Togo.

The trip was financed by USAID through the Division for International Development Cooperation, Ministry of Foreign Affairs, Israel, and the Geological Survey of Israel, Ministry of Energy and Infrastructure. I thank Dr. A. Bein, Director of the Geological Survey of Israel for permission and encouragement to undertake this mission, and Mr. M. Ron of the Israeli Foreign Ministry for all his efforts.

APPENDIX A

Bibliography of Research on the Precambrian Phosphorites of Togo

Aregba, A. and Aissah, S., 1986. Note sur les phosphates de Bassar: les extensions nord et sud de l'indice Bassar-Tcharchaminade. BNRM Report, 17 p.

Berthiaux, A., 1987. Recherches de phosphates à Bassar et Pagala. Etude des photographies aériennes. BRGM Report, 4, p., maps (1:50,000).

Berthiaux, A., 1988. Etudes morphostructurales de occurrences phosphatées de Bassar et de Pagala (interprétation des photographies aériennes. Annexe 4 to BRGM Report 88 TGO 003, 8 p.

Blot, A., 1985. Un nouvel indice de phosphates dans le centre du Togo: Bassar-Tchatchaminade. Orstom Reports 28, 5 p. and 28b, 7 p.

Blot, A., 1986. Géochimie des phosphates précambriens du Togo (février, 1986). Orstom Report, 7 p.

Castaing, C., 1987. Etude structurale des phosphates de Bassar (Togo). BRGM Report 127/GEE, 17 p.

Castaing, C., 1988. Etude structurale des phosphates protérozoïques de Bassar (Togo). Annexe to BRGM Report 88 TGO 003, 23 p.

Deh, V., Woeledji, U. and Siah, M., 1987. Resultats d'une prospection géophysique sur le gisement de phosphates de Bassar (Togo). BNRM Report, 17 p., App. 16 pl.

Godonou, K.S., 1987. Recherches des extensions sud des phosphates de Bassar. BNRM Report, 3 p. (App.).

Godonou, K.S., 1988. Recherches des extensions sud des phosphates de Bassar. Annexe 6 to BRGM Report 88 TGO003, 8 p.

Heimbach, W., Luttig, G. and Muller, H.W., 1987. Evaluation du géopotentielle du Togo Nord. Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Report.

Legendre, O., 1987. Etude mineralogique des phosphates de Bassar (Togo). BRGM Report, 8 p.

Pascal, M. and Aregba, A., 1988. Etude géologique et minière des phosphates précambriennes de la région de Bassar - Togo (Campagne 1987). BRGM Report 88 TGO 003, 117 p., maps.

- Roy, D. and Nimon, S., 1987. Rapport de mission sur le projet phosphates de Bassar (11/19 mai, 1987). BNRM Report, 6 p. (App.).
- Roy, D. and Nimon, S., 1988. Fiches d'études pétrographiques. Annexe to BRGM Report 88 TGO 003, 25 p.
- Rapport de mission sur le projet phosphates de Bassar (11/19 mai, 1987). BNRM Report, 6 p. (App.).
- Save, M., Barron, M. and Baudet, G., 1988. Evaluation préliminaire d'échantillons de minerai de phosphate de Bassar. BRGM Report DAM/MIN/88/No. 180.
- Save, M., Barron, M. and Baudet, G., 1988. Evaluation préliminaire d'échantillons de minerai de phosphate de Bassar. Annexe 3 to BRGM Report 88 TGO 003, 48 p., with App. on Analytical Methods; Mineralogical Analyses; Phosphoric Acid Production; Superphosphate Production.
- Slansky, M., 1985. La formation phosphatée de Bassar (Togo). Résultats de mission identification de juillet 1985. BRGM Report 85 TGO 015 GEO. 18 p.

