

# UNITED NATIONS ECONOMIC AND SOCIAL COUNCIL



55211

Distr.  
LIMITED



E/CN.14/MIN/7  
18 January 1968

ENGLISH

Original: FRANCAIS

Economic Commission for Africa  
Seminar on New Metals and Minerals  
Addis Ababa, 5-10 February 1968

## NEW MINERALS IN THE IVORY COAST

(submitted by the Government of Ivory Coast)

M68-132

Contents

	<u>Pages</u>
1. Introduction . . . . .	3
2. Geological Framework . . . . .	4
3. Titanium and zirconium minerals . . . . .	5
3.1 Concentration of titanium and zirconium ores in the coastal region of the Ivory Coast sedimentary basin	
3.1.1 The Addah deposits . . . . .	6
3.1.2 The Grand Lahou - Fresco deposits . . . . .	7
3.2 Rutile in the Man region . . . . .	10
4. Lithium and beryllium minerals . . . . .	11
4.1 The South-eastern region of the Ivory Coast	
4.1.1 Lithium and beryllium mineralisations - mode of occurrence . . . . .	12
4.1.2 Economic interest of occurrences of spodumene and beryl . . . . .	14
4.2 Central region of the Ivory Coast . . . . . (Bada-Pekaha-Haut N'zi)	16
4.2.1 Lithium mineralisations . . . . .	16
4.2.2 Beryl . . . . .	17
4.3 Boundiali Region (Touvré-Kouto)	
4.3.1 Lithium mineralisations . . . . .	17
4.3.2 Beryl . . . . .	17
4.4 Issia Region . . . . .	18
4.4.1 Beryl . . . . .	18
4.4.2 Lithium mineralisations . . . . .	18
5. Niobium (columbium) and tantalum ores . . . . .	19
5.1 The Touvré deposits . . . . .	20
5.1.1 Geology . . . . .	20
5.1.2 Colombo-tantalite mineralisations . . . . .	22
5.1.3 Prospection . . . . .	22
5.1.4 Estimates of Touvré colombo-tantalite placers . . . . .	23

	<u>Pages</u>
5.2 The Issia Region deposits . . . . .	24
5.2.1 Geological synopsis . . . . .	24
5.2.2 Colombo-tantalite mineralisations . .	26
5.2.2.1 Prospection . . . . .	26
5.2.2.2 Calculation of grades and reserves . . . . .	27
5.2.2.3 Chemical composition of ore	28
5.2.2.4 Methods of exploitation . .	29
5.3 Tantalo - colombite of the Bouaké and Korhago regions . . . . .	31
5.4 Colombo-tantalite of the Bada region . . . .	32
6. Monazite (rare earths) . . . . .	32
7. Conclusions . . . . .	33
8. Bibliography . . . . .	34

## NEW MINERALS IN THE IVORY COAST\*

### I. Introduction

The present note submitted for the Seminar on New Metals and Minerals organized by the Economic Commission for Africa to be held at Addis Ababa from 5 to 10 February 1968 should be considered as a synthesis of the work of various geologists and prospectors of the public<sup>(1)</sup> or private<sup>(2)</sup> sector who have worked in the Ivory Coast for the past fifteen years.

In this connexion it should be emphasized that SODEMI deserves special mention because it was that organization which, from 1963 on, re-commenced the prospection and study of pegmatites and their mineralisations (primary deposits, alluvial, eluvial and colluvial deposits) - "Operation Lithium-beryllium", "Operation pegmatites".

No doubt many technical geological details are lacking in this study but we have preferred to lay greater emphasis on the economic aspects of question.

---

\* by Joseph Nzi

- (1) DFMG - Direction fédérale des mines et de la géologie at Dakar.  
DGPM - Direction de la géologie et de la prospection minière  
at Abidjan.  
SODEMI - Société pour le développement Minier de la Côte-d'Ivoire,  
Société d'Etat, Abidjan.
- (2) BRGM - Bureau de recherches géologiques et minières.  
SAREMCI - Société anonyme de recherches et d'exploitations  
minières of the Ivory Coast at Bouaké

A detailed map of Ivory Coast (Côte d'Ivoire) showing its geographical features, major cities, and administrative boundaries. The map is oriented with North at the top. The coastline is on the west and south, bordering the Gulf of Guinea (GOLFE DE GUINEE). Major cities marked include Abidjan (the capital), Bouaké, Yamoussoukro, Daloa, Bouaflé, Ségoula, and others. Rivers shown include the Cavally, Sassandra, and others. The map also shows the borders with Liberia to the west, Ghana to the east, and Upper Volta to the north. A grid of latitude and longitude lines is overlaid, with latitude marked from 5°N to 10°N and longitude from 3°W to 8°W.

DMG-Abidjan .oct. 1967

0 100 200  
KILOMETRES

The useful minerals described in the following pages are found for the most part in the same geological context, but for reasons of convenience they have been separated and regrouped (titanium and zirconium minerals, lithium and beryl minerals, colombo-tantalites, and monazite).

## 2. Geological Framework

The Ivory Coast is a country of modest size, (322,500 km<sup>2</sup>) included between latitudes 4° 20' and 11° N. and longitudes 2° 20' and 8° 40' W.. It is bounded on the east by Ghana, on the west by Guinea and Liberia, on the north by the Upper Volta and Mali, and on the south by the Atlantic Ocean (Gulf of Guinea).

Its structure is that of a deeply-eroded platform sloping slightly towards the sea, with only a few slight changes of relief.

From the geological point of view, the Ivory Coast is part of the Pre-Cambrian shield of West Africa.

The Pre-Cambrian formations have a characteristic NNE-SSW structural alignment, granitic, gneissic and migmatic rocks alternating with para-metamorphic rocks (schists, mica schists, quartzites, etc.) upthrust vertically and sometimes associated with basic volcanic rocks in volcano-sedimentary complexes.

Massifs of plutonic rocks (granodiorites, diorites) are intrusive both in the metamorphic rocks and in the older granites.

The Upper Pre-Cambrian or Tarkwaian is represented by predominantly sandy sediments (sandstone-quartzite), weakly metamorphised, in Bondoukou region.

The best-represented Pre-Cambrian formations belong to the Middle Pre-Cambrian or Birrimian series.

The Lower Pre-Cambrian or Pre-Birimian is represented in the province of Man by gneiss, migmatites, and quartzites associated with magnetites, amphibolites, pyroxenites, and doubtless also by the charnockite complex of the Tabou-Béreby region.

The Ivory Coast coastal sedimentary basin (marine and continental) lies above the metamorphosed and granitized crystalline shield in discontinuous contact.

### 3. Titanium and Zirconium Minerals

#### 3.1 Concentration of titanium and zirconium ores in the coastal region of the Ivory Coast sedimentary basin

In 1955-1956, the former "Direction fédérale des Mines et de la géologie" undertook a general reconnaissance of the indications of zircon and titanium ores noted on the coast of the Ivory Coast, from Tabou to the Ghana frontier.

D. SOULE DELAFONT had already noted the presence of black sands to the west of Tabou.

Along the 300 km of shore-line prospected by auger drilling 92 cores were recovered from 516 shafts totalling 1,105 meters in depth; 224 samples were collected for examination.

This reconnaissance work revealed the absence of deposits of heavy minerals on the present beach east of Abidjan. On the other hand, to the west of Abidjan, from Vridi Channel (Canal?) to Fresco, over a length of 170 km, coastal belts lying below the present beach showed notable concentrations of black sands.

These concentrations, lying parallel to the present beach, are usually masked by an overburden of 1 to 3 meters of sterile sands.

First results of the analysis revealed the presence of some 20 mineral varieties, among them the following five useful minerals:

	<u>Average grade</u>
Ilmenite	18%
Zircon	0.5%
Rutile	0.2%
Monazite	trace
Gold	occurrence

Calculations of probable tonnage give a figure of 400,000 tons of ilmenite, of which 200,000 tons for the Addah deposit and 200,000 tons for the Grand-Lahou deposit. The ilmenite averages more than 50%  $\text{TiO}_2$ .

Later, from April 1959 to March 1961, the Société anonyme de recherches et d'exploitations minières en côte-d'Ivoire (SAREMCI) undertook, under its permits Nos. 828 to 845, the reconnaissance and detailed study of localised mineralisations in the Addah-Jacqueville and Grand-Lahou-Fresco regions.

The presence of ilmenite as the principal ore was confirmed. On the other hand, little hope was given for rutile and zircon.

Trenching and lines of pits sunk perpendicularly to the beach showed the presence of the ore below the hydrostatic level.

The sands rich in heavy minerals may reach 0.55 to 0.60 meters in thickness under several meters of stratified, cross-bedded sand. (Figure 2)

#### 3.1.1 The Addah deposits

In the Jacqueville region the only large mineralised layer extends parallel to the shore over a breadth of about 10 metres.

Its thickness varies from 0.50 to 0.60 m. before disappearing under the hydrostatic level.

Towards Addah the mineralised layers are rich and thick.



### 3.1.2 The Grand-Lahou-Fresco deposits

A good mineralised level was found, consisting of two layers separated by a sterile bed. Its maximum thickness is 2 metres and its average breadth 15 metres. In some places this layer is almost entirely below the hydrostatic level.

At Fresco, some drill holes encountered several mineralised layers.

Ground studies made by trenching and lines of HELIX auger-drill holes were checked by laboratory analyses and treatment tests.

The analyses, all made by the Bureau des recherches géologiques et minières (BRGM) in Paris, brought out the essential characteristics of the mineralisation.

More particularly, the following studies were undertaken:

1. Measurement of the average density of each sample by the picnometre method.

The average densities ranged from 2.7 to 3.6.

2. Granulometric study

Mesh sizes of the screen were the following:

0.08 mm, 0.20 mm, 0.27 mm, 0.35 mm and 0.5 mm.

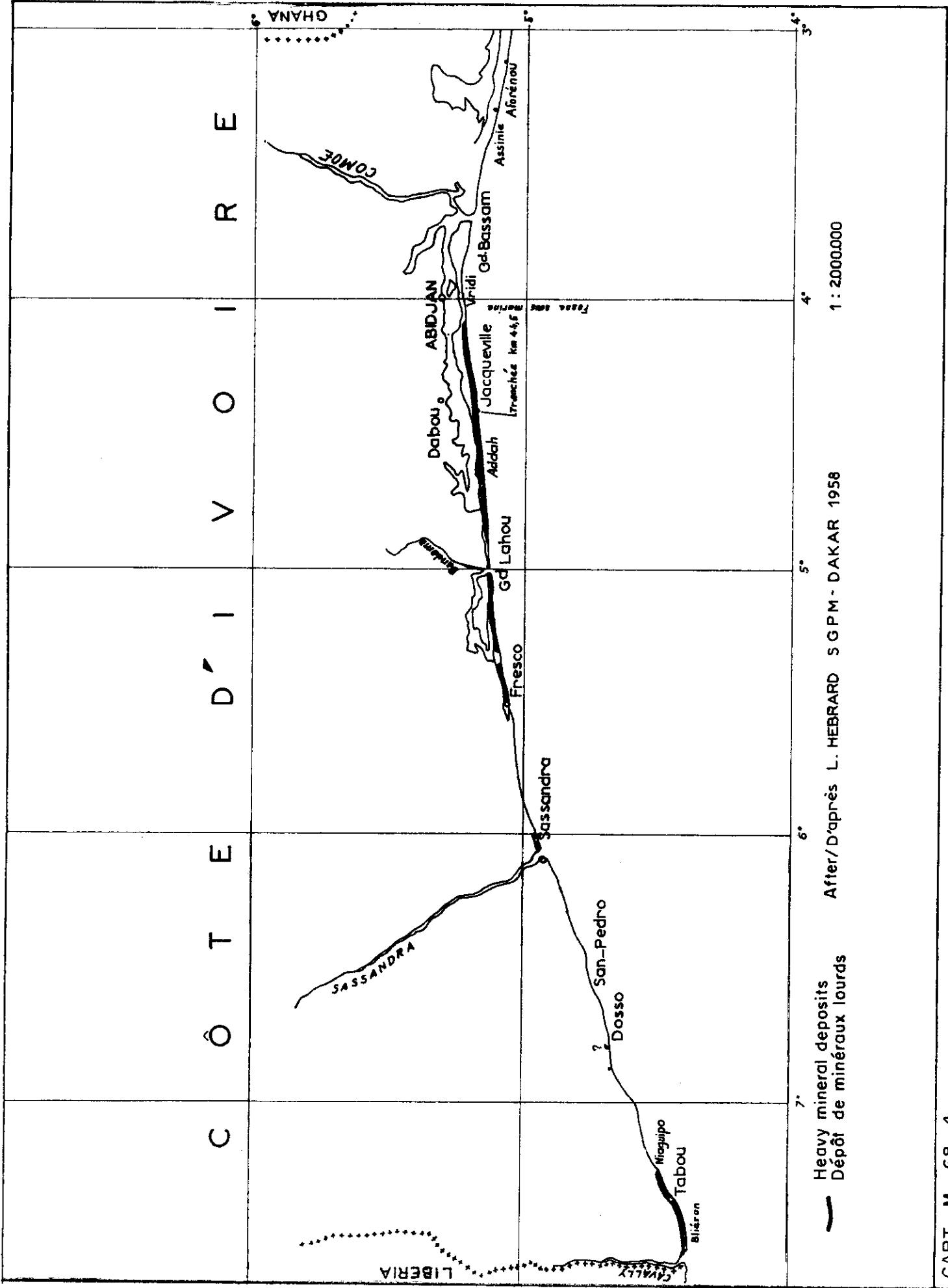
3. Densitometer study of each granulometric sample by immersion in dense liquor:

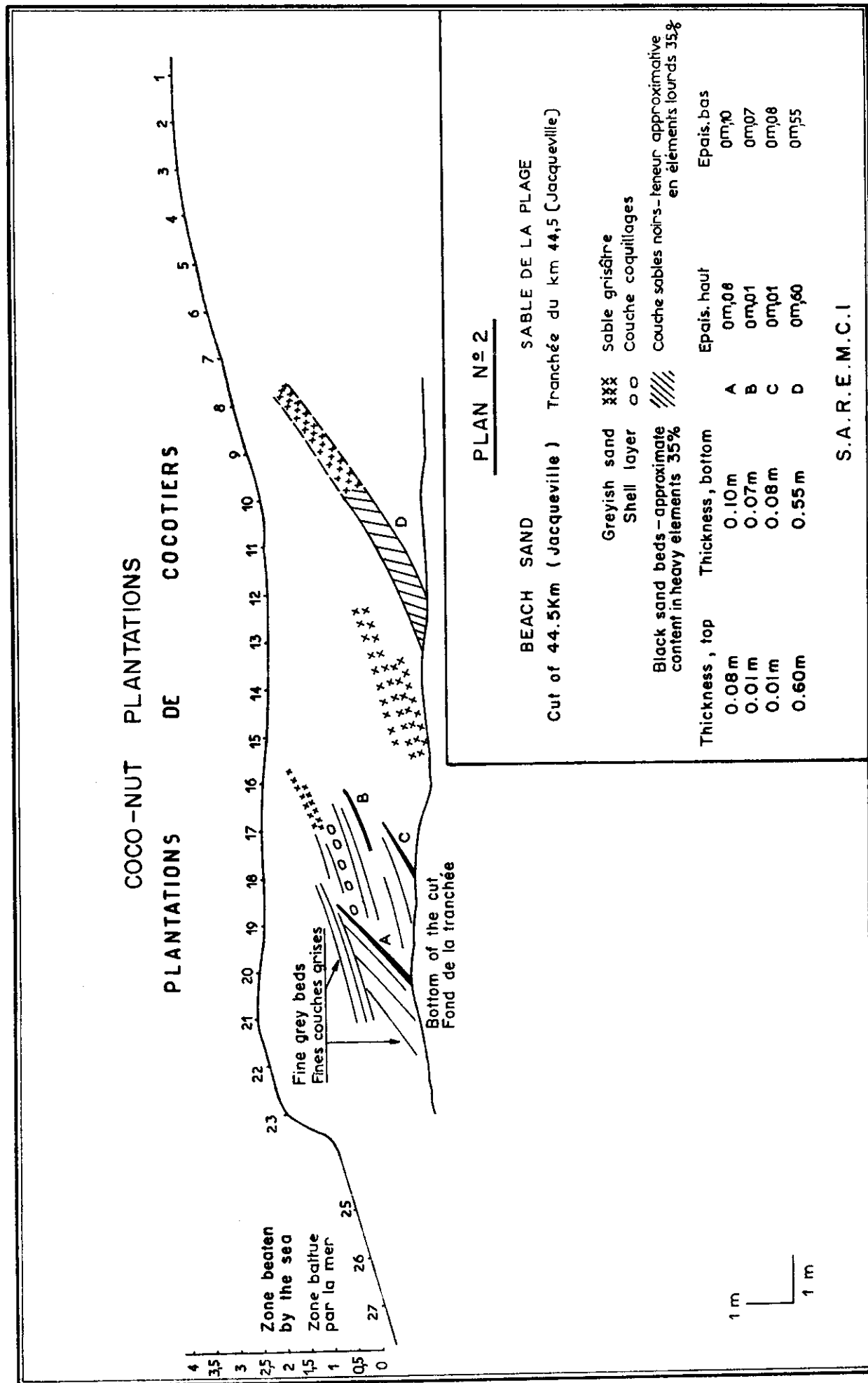
3 fractions of densities

- (1) below 2.9,
- (2) ranging from 2.9 to 3.3,
- (e) above 3.3.

The "heavies" were clearly concentrated in the fine fractions.

Fig. 2





4. Study of the titanium and iron values of each granulometric fraction.
5. Study of the magnetic behavior, with FRANTZ separator, of "heavy" fractions of each of the sands, obtained by densitometric separation (liquor of density equal to 3.3).
6. Mineralogical study of different fractions with the polarizing microscope for transparent minerals, and by qualitative microchemical analysis for opaque minerals.  
Statistical calculation served to evaluate the quantities of minerals present.
7. Studies of titanium and iron values of fractions obtained by electromagnetic separation.  
The high percentage of minerals reacting at 0.2A and 0.3A corresponds to ilmenite.
8. Study of magnetic behavior, with FRANTZ separator, of heavy fractions of each granulometric sample of sand.  
Results confirmed that the ilmenite is concentrated primarily in the two fractions 0.08-0.20 and 0.20-0.27.  
For titanium and iron values, analyses were made on the "electromagnetic" fractions obtained from the "heavies" of each granulometric sample.  
The highest tenors appeared in the fractions reacting at 0.2 and 0.3A and below 0.27 mm.
9. Study of the distribution of zircon and rutile in each of the sands as a function of granulometry  
Rutile and zircon were observed in the "heavy" fractions of the sands, but with respect to

magnetism were found in fractions reacting to fields higher than those used for ilmenite.

Rutile was concentrated in coarser granulometric samples, that is, higher than 0.5 mm, and ranging from 0.35 to 0.5 mm.

Zircon was concentrated preferentially in the fine fractions and seemed to follow ilmenite with respect to granulometry. It was concentrated in the (magnetically) less reactive fractions.

The study of Grand-Lahou sand gives an idea of the composition of the ilmenite. The maximum tenor of 55%  $\text{TiO}_2$  was obtained in the fraction reacting at 0.3A, which corresponds to the maximum tenor of non-magnetite ilmenites.

However, it was noted that ilmenite tested under the microscope in a fraction reacting at 0.2A showed a lower  $\text{TiO}_2$  tenor (51.3%). This phenomenon may be explained by the fact that the ilmenite very frequently contains ex-solutions of magnetite which make it more reactive and diminish the  $\text{TiO}_2$  tenor. Perhaps also, the tenor of 55% is explained by an inverse phenomenon: ex-solutions of rutile in ilmenite which render it less reactive and raise the  $\text{TiO}_2$  tenor.

First results being judged encouraging, SAREMCI in 1961 applied for 17 exploitation permits. Studies of treatment equipment for ilmenite sands were pursued in France at the same time as a systematic study of prospecting samples was carried out in the Bouaké laboratory.

The scheme for treatment of the Grand-Lahou mineralised sands projected in 1962 was the following:

- On-site pumping of sand, and transport by pipeline to the lagoon, where the concentrate would be loaded on barges;

- Simultaneously, study in France of electromagnetic and electrostatic treatment procedures on a sample of concentrate prepared by lavoflux from a collection of 1,200 litres of mine-run sand, carried out at Grand-Lahou.

A combination of electromagnetic and electrostatic procedures was also envisaged, as well as the use of electromagnetic separators with immersed belting (wet process), which would avoid a costly drying of the concentrate.

A pilot unit based on the LAVODUNE principle was deemed more effective than the Humphreys spiral technique.

The study of the samples from the Grand-Lahou deposits was completed at the end of 1964, but the reconnaissance of the Addah deposits continued into 1965.

The ilmenite reserves of the Grand-Lahou deposits were estimated at 128,000 tons.

In 1966 SAREMCI intended to prepare a project for exploitation, with a feasibility study of the ilmenite sands, but since then it seems to have preferred to defer this matter as quite marginal. It certainly is taking into account the difficulty of exploiting mineralised beds, a good part of which are below the hydrostatic level, as well as current international economic conditions (cessation of mining in Senegal).

### 3.2 Rutile in the Man region

From the foregoing it appears that, while not present in sufficiently large quantities to arouse an immediate economic interest, rutile is of frequent occurrence in the black sands of the coastal region of the Ivory Coast sedimentary basin.

Prospecting for this titanium ore has also been undertaken in the Man region (Mission CERES, 1957-1958).

Nearly 2,000 tons of ore were identified in the region of Ganleu, Feaplu and Singoiné, especially in the alluvium of the Youna river and its tributaries.

Titanium minerals, particularly ilmenite, are also well represented in the Agboville region. They are probably related to the basites of M'Blibo and Attinguié.

A similar situation exists in the Abengourou region (Zanaka, Bélou).

However, not nearly all regions likely to contain ilmenite have been prospected, but in present economic conditions the discovery of economically valuable deposits is unlikely.

#### 4. Lithium and Beryllium Minerals

##### 4.1 Southeast Region of the Ivory Coast

The credit for the first indication of spodumene discovered in the Agboville region goes to one of the missions of the former Direction de la géologie et de la prospection minière (DGPM) of the Ivory Coast (LEGAGNEUR, 1960-1962). This attracted the attention of investigators to the pegmatites of this region.

Other indications of spodumene and beryl were discovered later, especially by the BRGM missions in 1961 and 1962 (LETALENET).

The purpose of the Lithium-Beryllium mission (FRUTIGER, 1962-1963) undertaken by the Société d'état pour le développement minier de la Côte d'Ivoire (SODEMI) was to complete and finish the work of the earlier DGPM and BRGM missions.

These first surveys led SODEMI to establish its "Operation Pegmatites" to execute a programme of general surveys of Ivory Coast pegmatites and their mineralisations.

4.1.1 Nature of lithium and beryl mineralisations - mode of occurrence

The lithium ore encountered in this region is spodumene  $(\text{SiO}_3)_2 \text{LiAl}$  or  $4 \text{SiO}_2 \text{Al}_2\text{O}_3 \text{Li}_2\text{O}$ .

The beryllium ore is beryl  $\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$  or  $6 \text{SiO}_2 \text{Al}_2\text{O}_3 \text{BeO}$ .

Both are found either in the primary state in the mineralised pegmatites or in the eluvium.

4.1.1.1 Nature of granite massifs in connexion with Li and Be Mineralisation

These massifs are intrusive, concordant, syntectonic and synorogenic to tardiorogenic, in the form of elliptical domes with the long axis oriented in the Birrimian direction (NNE-SSW), presenting a generally oriented structure enclosing enclaves of country rock.

The chief granite massifs prospected are the following:

- Agboville massif
- Massif to the west of Kondiébouman
- Rubino massif
- Kotimpo massif
- Adzopé massif
- Massif to the south of Akoupé

The most interesting granites are characterised by their homogeneity and acidity.

4.1.1.2 General characteristics of beryl and spodumene pegmatites

These pegmatites occur as veins, lenses or mounds. They are numerous and can be quite well mineralised with beryl and especially with spodumene; unfortunately they are all small and seldom exceed 1 metre in thickness; veins



exceeding 4 to 5 meters in thickness are rare. From the point of view of paragenesis:

- the beryl pegmatites contain mainly feldspars (more or less albitised microcline and oligoclase, gray to greyish-blue, slightly translucent quartz, mica (most often green passing to white or dark brown), and black tourmaline; this green or light green gem-type beryl occurs in masses of crystals or in isolated prismatic crystals. The beryl pegmatites are found within and towards the borders of the granites. They are rarely found outside them.
- the spodumen pegmatites enclose gray quartz, mainly feldspar (albitised microcline and albite), and greenish white mica in flakes; the spodumene in long sticks is associated with a little garnet.

From the theoretical point of view the muscovite and beryl pegmatites and the green muscovite and spodumene-albite pegmatites of the Adzopé-Agboville region correspond to Fersman's Type 4 and the earlier members of Type 5.

Replacement phenomena generally accompanying the albitisation phase and ending in the formation of useful minerals are not pronounced.

The observed paragenesis would a priori be favorable for the presence of cassiterite and colombo-tantalite, but in fact none of these minerals has been observed, which indicates a real poverty of Sn, Nb, and Ta in the region. The crystallisation temperatures of the pegmatites of this region were too high. The presence of lepidolite would be an interesting indication of a "cooler" pegmatite, but unfortunately none has yet been discovered. One might search for it in pegmatites outside the granite, but few pegmatites penetrate the parametamorphic rocks bounding the granite.

#### 4.1.2 Economic interest of Spodumene and Beryl occurrences

The indications of spodumene found in rocks at Kondiébouman and to the south of Rubino, and those of beryl found in quartz veins and alluvium to the NE and SW of Agboville have no economic interest.

##### Spodumene

The most interesting lithium zone prospected is on the southeast border of the Adzopé massif, to the north of the Yakassé road. The only lithium-bearing mineral encountered, spodumene, was found in pegmatites and more rarely in alluvium (mission DGPM 1962).

These spodumene pegmatites generally include several veins distributed over an area of about 1 km<sup>2</sup>.

The average dimension of the veins is less than 1 metre with the exception of the principal vein which reaches 4-5 metres in thickness and 80 metres in length. However, this vein has only a low economic value. The smaller veins can have a tenor higher than 2%.

Analysis of the Kondiébouman pegmatite in the region of Agboville showed 0.23% Li<sub>2</sub>O.

##### Beryl

More interesting than those in eluvium or pegmatites, the alluvial deposits nevertheless have grades 10 to 20 times too low in the mineralised zones.

Besides the many indications of alluvial beryl in the Agboville region, a berylliferous zone of about 150 km<sup>2</sup>, and the small zone of Kamikro, have been found in the Adzopé massif.

The probable reserves of beryl in the prospected zone are estimated at 100-200 tons of beryl. The highest grades are 500-800 g/m<sup>3</sup> but the average is 10 to 20 times lower.

The largest beryl discovered weighs 320 g.

The alluvial beryl is found only in the interior of the granite massif.

The only interesting beryl discovery in eluvium was made at Kpassin, in the Agboville region. But except for one record grade of  $2,800 \text{ g/m}^3$ , the tenors are quite low.

Beryl is thus much rarer in eluvium than in alluvium. The results of surveys of the beryl pegmatites (direct surveys, systematic prospecting by pits and trenching) have thus been disappointing.

On the average, mineralisation is slight. The highest grade, from a pit in the Adzopé region, was  $2,340 \text{ g/m}^3$ , a grade barely equal to the limiting grade for exploitation.

The beryl pegmatites apparently contain no other useful substance.

A series of small beryl pegmatite veins was identified in the town of Agboville itself.

Indications of primary and alluvial beryl are also known in the massifs of Kotimpo (Agboville) and Bonahoin (Abengourou).

It should be noted that the beryl surveys have related especially to crystals visible to the naked eye.

Four chemical analyses of material from recognised beryl-bearing pits by the usual method of prospecting (tenors of the order of  $50$  to  $200 \text{ g/m}^3$ ) showed that tenors of Be varied from  $10$  to  $80 \text{ ppm}$  in the finer parts of the gravel (fraction smaller than  $3\text{mm}$ ), which theoretically represents much more beryl than tenors of  $50$  to  $200 \text{ g/m}^3$ .

A certain amount of work done by CEA (Commissariat à l'énergie atomique) indicates that a minimum grade of  $0.05\%$  BeO is required for the yield to be acceptable:  $500 \text{ ppm}$  of BeO or  $280 \text{ ppm}$  of Be.

Thus we are still below these figures, but changes in conditions of exploitability or in beryl prices perhaps may some day again raise the question of the economic value of these deposits.

#### 4.2 Central Region of the Ivory Coast (Bada-Pekaha - Haut N'zi)

Mineral interest in the Bada region is linked to the presence of a large area of mineralised pegmatites in contact with the Ferké granite and the Haut N'zi series. Bada is a small village situated on the Bouaké - Marabadiassa - Bouandougou road, about 3 km from the ferry from Marabadiassa to Bandama.

The Bada pegmatites include, among others, lithium-bearing minerals, beryl and colombo-tantalite.

##### 4.2.1 Lithium Mineralisations

The "Lilac Show" ("Indice Lilas") corresponds to a more or less spindle-shaped pegmatite formation whose average width is estimated at 3-5 metres, thickness about 35 metres, and depth more than 8 metres. The pegmatite, situated along a contact of the Ferké granite with Birrimian schists in course of granitization, has the special property of being lithium-bearing. The grade of the feldspar in  $\text{Li}_2\text{O}$  ranges from 188 ppm to 500 ppm as a consequence of the process of becoming sandstone ("greisénification"). However, the strongest concentrations of lithium are contained in the micas:

- violet mica (lepidolite?) 600-700 ppm
- greenish mica 1,300 ppm
- silvery white to greenish white mica 716 ppm

Other pegmatites with lithium-bearing micas of small thickness have been discovered in the mica-schists some 200 metres to the south of the "Lilac Show". The white mica is highest in lithium (2,000 ppm or 0.2%  $\text{Li}_2\text{O}$ ).

No other lithium mineral (amblygonite, spodumene, tryphylite or petalite) has been met with in the Bada region, but crystals of tantalite have been seen in situ in the pegmatite.

#### 4.2.2 Beryl

Beryl appears in situ in the pegmatites of the Sananbaho granite, a small, intrusive discontinuous massif of about 5 km<sup>2</sup>, located 5 km to the NW of Bada, in contact with the Ferké granite and the "Haut N'zi series".

Beryl has been seen in the Pékala-Kafiné region, to the south of Niakaramadougou as well as in the pegmatites of the Wong-N'zi sheet (syntectonic, geosynclinal granite with 2 micas, muscovite alone or biotite alone) to the north of the Katiola-Dabakala road.

### 4.3 Boundiali Region (Touvré - Kouto)

#### 4.3.1 Lithium mineralisations

The only zone of the Touvré region that seems interesting is the "Spodumene Hill" located 3.5 km NE of Touvré. Violet lepidolite and spodumene occur in isolated blocks of pegmatites .

These lithium minerals are accompanied by tantalum minerals.

The pegmatite appears in the form of aligned and altered blocks, enclosed in oriented and sometimes granitised amphibolites.

#### 4.3.2 Beryl

This mineral is found either in green muscovite pegmatites localised in the northern part of the Touvré pegmatite field, or in muscovite pegmatites located to the southwest of this field. In the first case beryl is not accompanied by colombo-tantalite; in the second case, colombo-tantalite mineralisations are found in eluvium.

From the economic point of view, secondary recovery of lithium and beryllium minerals, altogether quite rare in the pegmatites of this sector, can be envisaged only in case of an exploitation of the colombo-tantalites, a possibility at Touvré.

#### 4.4 Issia Region

##### 4.4.1 Beryl

Beryl has been found in the Issia region in alluvial, colluvial and eluvial placers mineralised with colombo-tantalite.

But while colombo-tantalite has never been met within the pegmatite rocks, centimetre-size prisms of gem-type beryl have been found in several pegmatites, especially those of the upper courses of the Brouhou and Gbéguéhi streams and those of the pegmatite field located on the granite dome 5 km N of Issia.

The colour of this beryl, closely associated with colombo-tantalite, varies from pale green to white.

Although reserves and tenor of beryl in the colombo-tantalite placers of the Issia region have not yet been systematically determined the extraction of beryl as a by-product of colombo-tantalite can be envisaged in case of exploitation of the latter. In effect, preliminary calculations indicate possible reserves of 20 tons of beryl of 11% BeO.

##### 4.4.2 Lithium Mineralisations

Indications of lithium-bearing minerals have been found in present alluvium, colluvium and eluvium.

A lithium-bearing mica tourmalinite (228 ppm  $\text{Li}_2\text{O}$ ) accompanying beryl pegmatite was found in the upper course of the Gbéguéhi stream.

In the same way, a fragment of aplogranite with very interesting spodumene mineralisation (9,600 ppm  $\text{Li}_2\text{O}$ ) or 0.96%  $\text{Li}_2\text{O}$ ) was found 3 km to the south of the village of Zuzua. Unfortunately, no spodumene or lepidolite pegmatite has been noted up to the present time.

From the geochemical point of view, geochemical studies for lithium have proved the excellent distribution of lithium in present soils and alluvium ( $\text{Li}_2\text{O}$  tests carried out in the SODEMI laboratory by flame spectrophotometry).

Geochemical analyses of rocks (granites, pegmatites, tourmalinites, and greisen with lithium-bearing muscovites) gave the following results:

granites: 280 and 350 ppm  $\text{Li}_2\text{O}$ ;  
large sheets of grayish muscovite : 1,360 ppm  $\text{Li}_2\text{O}$   
(pegmatite) (0.136%  $\text{Li}_2\text{O}$ );  
pegmatitic bedrock: 120, 170, 200, 215, 245, 315  
and 390 ppm  $\text{Li}_2\text{O}$ ;  
tourmalinite: 228 ppm  $\text{Li}_2\text{O}$ ;  
greisen: 180, 188, 280, 450, 550, 2,100, and 4,600 ppm  
 $\text{Li}_2\text{O}$

Tests on soils made in a few pegmatite and colluvial colombo-tantalite zones revealed no particular anomaly.

Geochemical alluvial prospecting showed a great number of lithium anomalies (90 to 320 ppm).

These anomalies are grouped in the zones of contact of the Issia granite massif, especially in the zones to the NE of Issia, to the east of Brokoua, and to the east of the Gogogbaya dome.

## 5. Columbium and Tantalum ores

The generic term colombo-tantalites is currently applied to mixed oxides of columbium and tantalum constituting an isomorphic, orthorhombic series. This series extends from tantalite to colombite, through the intermediate terms of colombo-tantalite and tantalo-colombite.

The colombo-titano-tantalates are mixtures of tetragonal oxides of titanium, columbium and tantalum, such as rutile, mossite and tapiolite.

The presence of columbium and tantalum minerals has been noted by geologists and prospectors, especially in the Central region (Béoumi, Bouaké, Tiebissou, Yaokro, Dabakala, Bada), in the southeast (Kravassou, Agboville, Adzopé), in the southwest (gold-panning sites to the NW of Tabou-Blidouba at Sago, 40 km to NE of Sassandra, to the north of Guedeyo), and in the Odienné region.

However, in the present state of affairs, only three deposits have been discovered: the Touvré deposits to the north of Boundiali, those of Issia in the Dalva region, and of the Bouaké penal camp, whose exploitation was stopped by SAREMCI in January 1966 after a total production of 14,500 kg since 1957.

#### 5.1 The Touvré deposits

The first indications of colombo-tantalite were noted in the Touvré region by R. COUTURE, a geologist (1958). In 1959 this region was the subject of several alluvial and eluvial prospecting investigations (PERONNE) which revealed the presence of colombo-tantalite pegmatites comprising a field 4 km long by 1 km wide to the east of Touvré. These pegmatites are emplaced in amphibolites and mica-schists.

Interesting colombo-tantalite mineralisations were then discovered primarily in the eluvium, with an average grade of 100-200 g/m<sup>3</sup> (maximum, 2 kg/m<sup>3</sup>).

The study of the pegmatites and their mineralisations was resumed in 1963 by SODEMI and integrated with the plan of "Operation Pegmatites" (H. ADAM, H. CRUYS, J.J. FRUTIGER).

##### 5.1.1 Geology

The region located between Touvré and Kouto is constituted of parametamorphic formations (more or less oriented amphibolites, mica-schists, arkoses) surrounded by granite formations (granites, diorites, micro-diorites, granodiorites, micro-granodiorites, gneiss).

The pegmatites are intrusive, either in the parametamorphic formations (chiefly in the amphibolites), or in the granites.



Of 5 types of pegmatites characterised by minerals visible to the naked eye, two present colombo-tantalite mineralisations:

- A type with lepidolite, muscovite, spodumene, colombo-tantalite;
- A type with green muscovite and colombo-tantalite.

The first type has been described in only one place, on "Spodumene Hill", 2.5 km NE of Touvré. The pegmatite outcrops in aligned and altered blocks.

The "Spodumene Hill" pegmatite is related to the underlying granite which sometime granitizes the enclosing amphibolite rock. It includes all phases of the colombo-tantalite orthorhombic series: colombite ( $d = 5.65$  to  $5.77$ ), colombo-tantalite, tantalocolombite, tantalite ( $d = 6.87$ ).

The second type of colombo-tantalite pegmatite, described at 1.5 km SE of Touvré, constitutes the region's chief source of colombo-tantalite.

The colombo-tantalite, found in abundance in eluvial or neighboring colluvial deposits, has grades often exceeding  $1 \text{ kg/m}^3$ .

This type of pegmatite is linked with the Touvré migmatitic granite, emplacement occurring in the oriented amphibolites (whether or not granitised) and the mica-schists.

Three types were distinguished:

- a type with green muscovite and beryl
- a type with muscovite and beryl
- a type with biotite and magnetite

The type with green muscovite and beryl, mentioned in connexion with indications of beryl, offers slight interest from the point of view of colombo-tantalite indications.

The biotite, magnetite type, also surrounded with granite, seems to have given rise to colombo-titano-tantalite indications which abound in the eluvium of the sector.

### 5.1.2 Colombo-tantalite mineralisations

It is convenient to distinguish two groups: the colombo-tantalites (s.l) and the colombo-titano-tantalates, sometimes called ilmeno-rutiles.

The colombo-tantalites (s.l) include: the tantalites ( $\text{Ta}_2\text{O}_5$  (Fe Mn) O with sometimes Sn, W, Ti, Mg, U, etc... ( $\text{Ta}_2\text{O}_5$  higher than 70%);

The colombo-tantalites ( $\text{Ta}_2\text{O}_5$  : 70-50%;

The tantalo-colombites ( $\text{Ta}_2\text{O}_5$  : 50-20%);

The colombites  $\text{Nb}_2\text{O}_5$  (Fe, Mn)O with sometimes Ti, Sn, W, Mg, etc... ( $\text{Ta}_2\text{O}_5$  below 20%)

The colombo-tantalites of the Tourné region are characterised by their low grade of titanium (Ti O<sub>2</sub> below 4%), the constant grade of MnO (between 11 and 13.5%), and a combined ratio of  $\text{Ta}_2\text{O}_5$  and  $\text{Nb}_2\text{O}_5$  lying between 75 and 85%.

The colombo-titano-tantalates are characterised by high proportions of Ti, Fe and Mn and constitute a supposed isomorphic mixture of tapiolite ( $\text{Ta}_2\text{O}_5$ , FeO), mossite ( $\text{Nb}_2\text{O}_5$ , FeO), and rutile ( $\text{TiO}_2$ ).

These mineralisations have been seen in eluvium and alluvium in the pegmatite zones.

The Tourné colombo-tantalite mineralisations comprises a mixture of colombite, tantalo-columbite, colombo-tantalite, and tantalite, with a quite high proportion of tantalo-colombite. It is generally linked to the muscovite pegmatites intrusive in para-amphibolites.

### 5.1.3 Prospecting

(1) Reconnaissance prospecting of the Tourné region with a view to finding an extension of mineralised zones previously recognised by geologists and prospectors.

(2) Semi-systematic prospecting of zones mineralised with Ta and Nb.

(3) Systematic prospecting of 3 sectors selected by semi-systematic prospecting.

5.1.4 Estimates of the Touvré colombo-tantalite placers

These estimates related to the tantalite-colombite and colombo-tantalite zones; the colombo-titano-tantalates were ignored for the moment.

Calculations were made on the basis of a limiting grade of exploitability of 50 and 100 g/m<sup>3</sup>. This limiting grade was fixed somewhat arbitrarily, taking into account the fact that at Issia, the limiting grade was fixed at 30 g/m<sup>3</sup> for a better quality of ore.

Coefficient of recovery adopted: 1.2

Method of sampling by sections from the whole depth of the pit.

The reserves of "Spodumene Hill" were estimated by a grid of pits at from 50 to about 20 tons of colombo-tantalite or tantalite-colombite.

From the point of view of granulometry, two-thirds of the ore has a size between 1 and 4 mm and one-third above 4 mm, at more than 70% Ta<sub>2</sub>O<sub>5</sub> + Nb<sub>2</sub>O<sub>5</sub>.

The two other zones worthy of interest are estimated at respectively 10 and 11 tons of ore. These figures correspond to minimal values.

In total: 41 tons of ore with a limiting grade of 50 g/m<sup>3</sup>  
or 37.6 tons with a limiting grade of 100 g/m<sup>3</sup>

This estimate was considered pessimistic, since it was incomplete. On the other hand, since the market value of the ore is uncertain, the limiting grade can vary and the estimate will have to be re-calculated. Moreover, the coefficient of recovery is open to question.

From the economic point of view, the Touvré colombo-tantalite ore, which has a high tenor of manganese (12 per cent), might be worked on a small scale. The problem of water would then arise, making exploitation possible only during the rainy season.

## 5.2 The deposits of the Issia region

The first reconnaissance surveys of the occurrence of colombo-tantalite in the Issia region were undertaken during the second semester of 1963 based on indications that an inhabitant of Sekouan, a village 4 km NW of Issia, brought to the attention of the Service des mines and SODEMI. Issia is an important sub-prefecture of the department of West Centre, situated on the Dalva-Gagnoa road.

The reconnaissance prospecting, in the framework of SODEMI's "Operation Pegmatites", permitted the location of a certain number of interesting zones, the semi-systematic prospecting of which was completed at the end of April 1965.

From July to September 1965 two trainees of the School of Mines at Nancy were entrusted with a study of the exploitation of the Issia region's colombo-tantalite placers.

### 5.2.1 Geological Summary

The geological formations of the Issia region are of Pre-Cambrian age. They are nevertheless almost entirely covered by recent formations: alluvium, colluvium and eluvium. Large lateritic carapaces have not been observed.

The Pre-Cambrian sub-basement of the Issia region is constituted chiefly of syncinematic granites appearing in parametamorphic country rock, formed by sub-vertical (dips of  $70^{\circ}$  to  $80^{\circ}$ ) of schistose rocks. The whole formation is oriented in the Birrimian NNE-SSW direction.

The granite massifs have developed a contact metamorphism in the Pre-Cambrian sediments, exhibiting itself in the presence of micaceous minerals, a rich development of staurotide, tourmaline

and garnet. These same granites are the source of large pegmatite, pneumatolytic and hydrothermal phenomena (pegmatites, tourmalinites, greisen, quartz).

The granite of the domes of Issia, Bitapia, Lobo, and Gogobaya is syn-to post-tectonic, calcalkaline (microcline, albite and oligoclase), with two micas. This granite is generally grainy, often with a porphyroid tendency, and oriented in the zones of the massifs surrounding the batholith. Schistose and paragneissic xenolith on the free borders have been found in abundance on the Issia dome.

The pegmatites occur within and around the batholith; they are especially numerous on the borders of the Issia granite massif. However, they are rarely seen in its widely spread zones of contact. These pegmatites have thickness varying from a few centimetres to a metre.

From the paragenetic point of view, the pegmatites surveyed in the Issia region can be classified into four types. The two first offer no economic interest, but the two last include colombo-tantalite and beryl mineralisations as well as typical minerals (quartz, perthitic microcline, muscovite, black tourmaline, apatite). The pegmatites of these two types are related to the boro-fluorine and sodolithio pegmatites.

The aplites, as frequent as the pegmatites, are affected by the same phenomena of crystallisation in monoclinic epidote and chlorite, and by the formation of nontronite (a complex hydrated silicate of iron belonging to the montmorillonite group.) This nontronite, a greenish yellow alteration product, invades the crystals and cracks of the feldspar sheets.

The tourmalinites formed in the pegmatite walls and the greisens, composed chiefly of quartz and silvery and greenish lithium-bearing micas, are well developed in the granite-schist zones of contact.

The vein-type quartz has been found injected in both the granites and schists.

#### 5.2.2 Colombo-tantalite mineralisations

##### 5.2.2.1 Prospecting

Mineralisations of alluvial, colluvial and eluvial colombo-tantalite and tantalocolumbite have been localised, like those of beryl and lithium, in the peripheral and contact zones of the Issia and Bitapia granites.

These colombo-tantalite indications were prospected in the colluvium by open trenches in some pegmatite bodies, and more recently by pits in alluvium, colluvium and eluvium.

The pits, 1.20 m x 0.80 m in section, were generally sunk to bed-rock. For each pit, six pans (45 to 48 litres of gravel) were washed. The pans were filled by sectioning the layer of gravel or by sampling of the mass of gravel mixed with a shovel. However, 7 alluvial pits were washed in their entirety.

The preliminary survey of the colombo-tantalite mineralised zones was followed by a semi-systematic prospecting of some of the better zones with a view to determining their economic interest. Six zones were chosen for this semi-systematic investigation.

Zone Etienne: located 4-5 km NW of Issia

Zone I: on the middle course of the Brouhou,  
about 3 km E of Issia

Zone IIa: 4.5 km E of Issia

Zone IIb: 5 km E of Issia

Zone III: 5.5 km ENE of Issia

Zone IV: 0.5-2.5 km N of Issia (upper  
course of the Brouhou and 3 small  
tributaries on the right bank).

Twenty-three placers of varying size were located. However, the colombo-tantalite mineralizations are irregularly distributed in the valleys, with a granulometry higher than 1 mm (75 per cent) included between 0.5 and 1 mm (17 to 18 per cent), 0.16 and 0.5 mm (6.5 - 8 per cent). The grades are also very irregular but the highest were found in alluvium.

#### 5.2.2.2 Calculation of grades and reserves

For calculation of the grade per  $m^3$  of gravel in place of the mineralised pits, it was necessary first to adopt a coefficient of recovery of the order of 1.2 as at Touveré, and to multiply by 25 the weight of colombo-tantalite tested in the concentrate.

The grade in grammes per  $m^3$  excavated is expressed as follows:

$$\text{Grade of material excavated} = \frac{\text{Grade of gravel} \times \text{thickness of gravel}}{\text{total sterile thickness and gravel}}$$

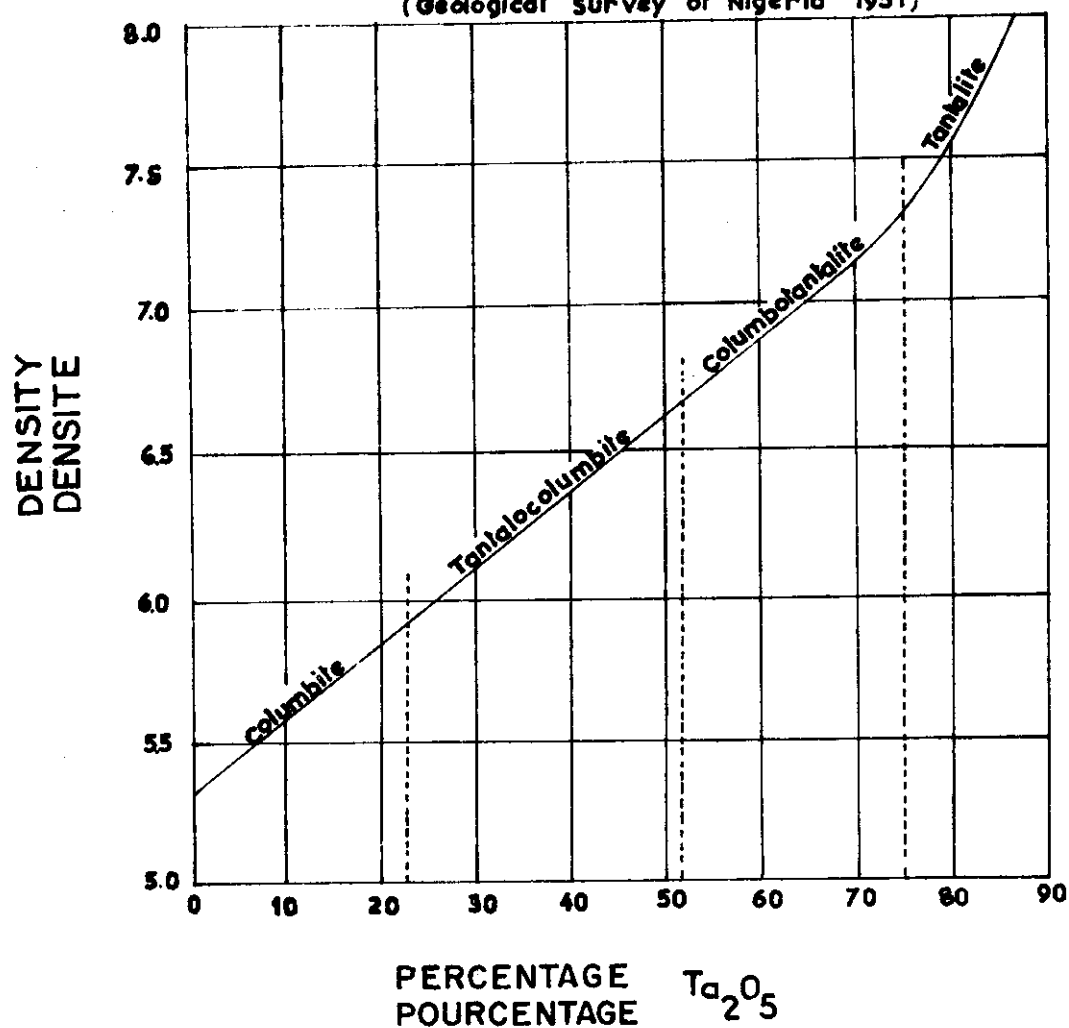
The estimate of possible reserves of colombo-tantalite placers was made by increasing calculated reserves by one-third. In effect, it was noted that the average grade per  $m^3$  of the total gravel of several alluvial pits was more than 50 per cent higher than that found by washing 45-48 litres of gravel (a cheap, practical method, but less accurate).

Conceding that the coefficient of recovery in eluvium and colluvium is equal to 1.58 instead of 1.2, the grade of the pits can be multiplied by 1.32.

Grade of gravel of alluvial pits washed in entirety = 1000  $g/m^3$   
Grade of 45-48 litres of washed gravel: 1,160  $g/m^3$

# GRAPH BY J.S. WEBB GRAPHIQUE DE

After / D'après R.R.E. JACOBSON et al: The occurrence  
of columbite in Nigeria  
(Geological Survey of Nigeria 1951)



The values of  $Ta_2O_5$  in the graph are subject to maximum variation of  $\pm 10\%$  with respect to values of analyses.

Les valeurs de  $Ta_2O_5$  d'après le graphique sont sujettes à une variation maximum de  $\pm 10\%$  par rapport aux valeurs d'analyses.



Taking as the limiting grade of exploitability  $30 \text{ g/m}^3$  excavated, the reserves of the 6 best zones of the Issia region are estimated at about 75 tons, irregularly distributed among 23 alluvial, colluvial or eluvial zones covering about  $500,000 \text{ m}^2$ . The average thickness to be excavated is 1.5 m, of which 0.88 m is gravel.

Semi-Systematic	Possible reserves in kg	Average grade of excavated material $\text{g/m}^3$
Zone Etienne	47 500 - 51 500	135
Zone I	10 675	91
Zone II a	2 040	343
Zone II b	10 545	93
Zone III	4 475	66
Zone IV	8 585	70

#### 5.2.2.3 Chemical composition of ore

The composition was determined by chemical methods, by physical tests (X-ray fluorescence), or by using the graphic method of J.S. WEBB, which translates variations in density as a function of the percentage of  $\text{Ta}_2\text{O}_5$ .

The chemical analysis was made by the SODEMI laboratory at Abidjan.

Although the composition of the Issia ores is not constant over the whole deposit, it may be asserted that they are true "colombo-tantalites" with an average grade in  $\text{Ta}_2\text{O}_5$  of 61 per cent and an average grade in  $\text{TiO}_2$  below 4 per cent. However, the ores discovered 10-15 km NE of Issia (Brokoua) are "tantalo-columbites" (40 per cent  $\text{Ta}_2\text{O}_5$  and 25 per cent  $\text{Nb}_2\text{O}_5$  with 5-7 per cent  $\text{TiO}_2$ ).

#### 5.2.2.4 Methods of exploitation

Economic studies for an eventual working of the Issia colombo-tantalite deposits envisage either a mechanised or an artisan-type exploitation.

Mechanised exploitation, requiring large investments, can be envisaged only for large reserves and low grades.

At Issia, dragline excavation and a mobile washery for ore-washing can be envisaged, especially for the Etienne zone placers.

Mechanised exploitation, permitting a good ore recovery, has the inconvenience of being costly. Besides, it requires a large and constant supply of water.

The cost of such an operation would be from 100 to 120 fr. CFA/m<sup>3</sup> of gravel, the sterile overburden being non-existent or small as in the colluvial/eluvial placers of the Etienne zone. From this cost are excluded amortization of the costs for prospecting and heavy mechanical equipment. At an average price of Fr. CFA 2,000 per kg of columbo-tantalite at 60 per cent Ta<sub>2</sub>O<sub>5</sub>, this cost corresponds to about 50-60 g of ore.

On the other hand, fr. CFA 4 to 5 million would have to be provided as indemnification for the various plantations covering these colluvial/eluvial colombo-tantalite placers.

For the alluvial placers, the cost would be only fr. CFA 70-80/m<sup>3</sup> excavated, or the equivalent of 35-40 g of columbo-tantalite.

Artisan-type exploitation, better adapted to quite rich small placers like those of the Issia region, has the advantage of limiting investment costs. Licences might be granted to private persons who thus would have the right to exploit well-defined sectors methodically. The ore produced would be sold to SODEMI, which would supervise the exploitation with Service des mines engineers.

However, in order to improve the yield, use could be made of the shaker and hand-jig, the long-tom, or motor-sluices and perhaps the slime-classifier (tantalo-columbite of Bouaké).

In all cases, the problem of water is of basic importance. The cost per cubic metre excavated by artisan methods would be, for the eluvial/colluvial placers of the Etienne zone, fr. CFA 254 (including fr. CFA 12 for indemnification of plantations); and for the alluvial placers of the Issia sector, fr. CFA 146.

These costs are arrived at by applying the following formula:

$$\frac{15}{H} + 60 + 200 \frac{h}{H} \quad \begin{array}{l} (h = \text{average thickness of gravel in metres}) \\ (H = \text{average thickness of gravel + sterile material, in metres}) \end{array}$$

- a formula deriving from a study by the geologist, M. ROCHAT, of the gravels of the Abidjan region.

15 fr. CFA/m<sup>2</sup> = cost of land clearing, per man per day

60 fr. CFA/m<sup>3</sup> = cost of mining, per man per day

200 fr. CFA = cost of washing and screening /m<sup>3</sup> of gravel

If the average value per kg of ore is assumed to be fr. CFA 2,000, for an average depth to be excavated of 1.5 m, the limiting grade rises to 135 g/m<sup>3</sup>, which corresponds to a grade of 1 g/m<sup>3</sup> for gold mining (acceptable for artisan exploitation).

Whatever be the method of exploitation, the recovery of beryl and gold as by-products of the colombo-tantalite may be considered as paying.

Beryl in sizes of 0.5 to 5 cm would be recovered by hand-picking of the gravel by operators of jigs and sluices.

In the same way, the gold content of colombo-tantalite of sizes below 1 mm could be recovered by amalgamation.

The sampling, to which SODEMI is now proceeding (preparation of three lots of 500 kg each) should soon give a more precise idea of the commercial value of the Issia colombo-tantalites.

### 5.3 Tantalo-columbite of the Bouaké and Korhogo regions

Many indications of tantalo-columbite have been found in the Bouaké region, especially in the Béoumi-Bouaké-Tiébissou triangle. Prospecting for this ore was undertaken in this zone by SAREMCI (Société anonyme de recherches et d'exploitations minières en Côte d'Ivoire), whose first exploration permit (obtained in 1952) was later (April 1953) converted into an exploitation permit. Further exploration led SAREMCI to apply, in 1953, for 104 permits in the region of Bouaké alone, and for 2 permits in the Korhogo region. The first surveys showed that the columbium-bearing mineralisations of the region are composed of a series of spots of small size.

#### Results of Analysis (1953)

	<u>Bouaké</u>	<u>Korhogo</u>
$Ta_2O_5$	12.10	10.60
$Nb_2O_5$	66.70	47.18
$TiO_2$	1.04	11.34
FeO	6.26	8.83
MnO	12.361	0.32

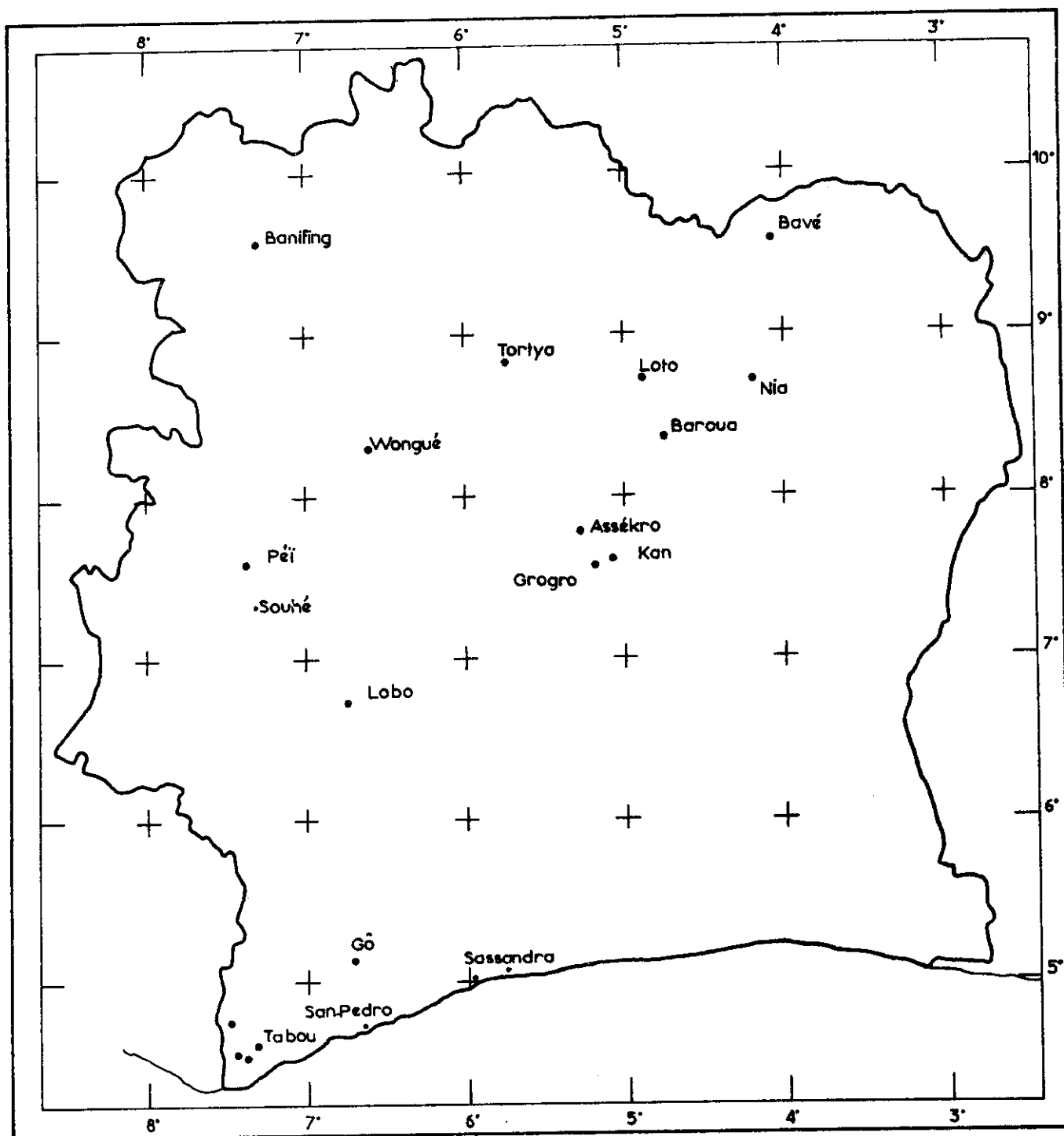
**Fig. 5**



SYMBOLS =  
SYMBOLS

Ta = Tantalite  
Zr = Zircon

Fig. 6



After / d'après SODEMI

GISEMENT ET INDICES MINÉRAUX  
MINERAL DEPOSITS AND OCCURRENCES

0 100 200  
Kilometres

## MONAZITE

RARE EARTHS AND THORIUM  
TERRE RARE ET THORIUM

- Occurrences containing 8-10% of concentrate  
Indices à teneur 8-10% du concentré
- Occurrences of coastal sands  
Indices de sables côtiers

Feb. - Fev. 1967

The only centre of mining is 3 km from Bouaké on the road to Bécoumi.

The mineralisation covering the granite plateau seems to be in strict relation to the formations of vein quartz and very abundant white mica.

Ore extraction is by scraping the gravelly surface layer with a bulldozer.

Washing is done on the spot. The idiomorphic or sub-idiomorphic crystals of columbite are extracted by a system of bucket-chains, while the gravel, a commercially useful product, is set aside.

The annual production of this operation was about 2 tons.

Since 1966 SAREMCI has stopped into modest operation at Bouaké after a total production of 14.5 tons of columbite.

#### 5.4 Colombo-tantalite of the Bada region

Colombo-tantalite (between 5 and 20 per cent), poor in Ta but rich in Ti and FeO (colombo-titano-tantalate) has been seen with beryl not only in place in the pegmatites of the Sananbaho granite massif, but also in alluvium, with grades reaching  $1.8 \text{ kg/m}^3$ .

Better grades of colombo-tantalite, rich in tantalum ( $1 \text{ kg/m}^3$ ) have been found in the eluvium of the "Lilac Show" pegmatite, but cannot form large reserves.

#### 6. Monazite (Rare Earths)

Alluvial indications of monazite are numerous in the Agboville region, but their economic interest is nil.

Monazite is usually a phosphate of rare earths, particularly of cerium, sometimes containing thorium and yttrium, but the chemical composition of the Agboville monazites is unknown.

Besides indications of monazite in coastal sands having no economic value, other indications of a more important grade (8-10 per cent of the concentrate) have been noted in various regions of the Ivory Coast, especially in the

Bouaké region, in the northeast (Bavé, Loto, Baroua, Nia), at Tortiya N of Séguéla (Wongué), in the Man region (Péi, Souhé), and in the region of Tabou.

In fact, monazite always occurs with pegmatites of the "high temperature" type, with biotite and magnetite for example. Interesting grades have occasionally been noted in BRGM reports (Operation SASCA in the southwest of the Ivory Coast), but no prospecting specifically for this mineral has been carried out.

On the other hand, xenotime is frequently associated with monazite in the Ivory Coast.

It should be noted that "rare elements" and "rare earths" are localised in pegmatites of the "hot" type never containing "paying" ores of lithium, tin or beryllium.

It follows that no precise study of minerals like monazite and xenotime can be made at this time, because the biotite and magnetite pegmatites attract little attention from prospectors. However, study of them might be "pushed" in connexion with uranium prospecting.

## 7. Conclusions

The mineralised sands of the Ivory Coast shore no doubt conceal interesting concentrations of titanium and zirconium ores, but their exploitation still remains doubtful.

Although indications of lithium and beryllium are frequent in the southeast of the Ivory Coast (Agloville and Adzopé region), their economic interest is low. However, secondary recovery of lithium and beryllium minerals might be envisaged in connexion with an exploitation of the colombo-tantalites of Touvré (columbite) and Issia (tantalite).

Particular attention has been given to the colombo-tantalite deposits of Touvré in the Boundiali region, and of Issia in the Daloa region, for which estimates of reserves have been made. Having regard to the widespread distribution of the ore both as regards deposits and grades, the estimates have varied somewhat in strictness. An eventual exploitation of these deposits would have to take account of the evolution of technology as well as of current international economic conditions.



8 - BIBLIOGRAPHY

- ADAM H. (1965) Etude et prospection des pegmatites du Nord de  
Bouaké SODEMI - Abidjan
- ADAM H. (1966) Mission pegmatites - campagne 1965-1966  
Région Touvré-Kouto SODEMI - Abidjan
- ADAM H. (1967) Exploration pour pegmatites de la région  
Dyogo-Tora Fandasso (Sud-Ouest de  
Boundiali) SODEMI - Abidjan
- BAGARRE E. et TAGINI B. Carte géologique de la Côte d'Ivoire à  
(1965) l'échelle du 1 000 000 à SODEMI - Abidjan
- CEREZ J. (décembre 1956) Prospection des sables noirs des plages de la  
région de Tabou et de Sassandra (Côte  
d'Ivoire) DFMG - Dakar
- CRUYS H. (1965) Prospection pour colombotantalite dans la région  
d'Issia campagne juillet 1963.  
- Avril 1965 SODEMI - Abidjan
- CRUYS H. (1965) Note complémentaire au rapport "prospection pour  
colombotantalite dans la région d'Issia"  
SODEMI - Abidjan
- DUCELLIER J. (1963) Géologie du Niobium et du Tantale.  
Chronique des Mines et de la recherche minière  
n<sup>os</sup> 317 et 318 mars-avril 1963.
- DOUCET M. et MACHET R. (1965)  
Possibilités d'exploitation du gisement de  
columbotantalite d'Issia  
- SODEMI - rapport de stage - Ecole Mines de Nancy
- FRUTIGER J.J. (1963) Indices minéraux de la région d'Agboville (autres  
que ceux de diamant, lithium et béryllium).  
SODEMI - Abidjan
- FRUTIGER J.J. (1963) Note sur les occurrences lithiques de la région  
d'Agboville SODEMI - Abidjan

- FRUTIGER J.J. (1963) Rapport final sur les travaux de la mission  
Lithium - Béryllium dans la région d'Agboville  
SODEMI - Abidjan
- FRUTIGER J.J. (1963) Occurences de Béryl dans la région d'Agboville  
SODEMI - Abidjan
- HEBRARD L. (Septembre 1957)  
Rapport sur les travaux de reconnaissance  
effectués au cours des mois de mai, juin, juillet,  
août 1956 sur les indices de minerais de Titane  
et de Zircon de la région littorale du bassin  
sédimentaire de Côte d'Ivoire entre Fresco et  
la frontière du Ghana.  
DFMG - Dakar
- HEBRARD L. (Octobre 1958)  
Aperçu sur les dépôts de minéraux lourds, Ilménite,  
Rutile, Zircon, Monazite .... des sables de plages  
d'Afrique Occidentale Française  
SGPM - Dakar
- LETALENET J. (1961) Rapport préliminaire sur la prospection des granites  
du Sud-Est de la Côte d'Ivoire.  
(Région d'Abengourou) BRGM - Abidjan
- LETALENET J. (1962) Rapport sur la prospection des granites du Sud-  
Est de la Côte d'Ivoire - Région d'Agboville.  
BRGM - Abidjan
- SAREMCI  
Rapport d'activité sur les permis de recherches  
n<sup>os</sup> 828 à 845 pendant la période du 1<sup>er</sup> avril  
1959 au 1<sup>er</sup> mars 1961.  
  
Rapport sur les travaux effectués sur les "P.R.B."  
n<sup>os</sup> 732 et 733 - Région de Fresco  
  
Rapports annuels 1952 - 1953 - 1954 - 1955 - 1956 -  
1957 - 1958 - 1959 - 1960 - 1961 - 1962 - 1963 -  
1964 - 1965 - 1966.

... / ...

SODEMI

ZANONE L. (1967)

Rapports annuels 1964 - 1965 - 1966

Atlas au 1/4 000 000 des gisements et  
indices minéraux de Côte d'Ivoire

SODEMI - Abidjan