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The Uranium Exploration History of the Central African Republic

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Abstract: The Uranium exploration history of the Central African Republic (CAR) extends on two periods separated by the independence in 1960, of the ex-Ubangi-Chari, a colony of French Equatorial Africa. The uranium research is contemporary of the French Atomic Energy Commission (CEA) implementation in this country in 1947 and done by the CEA. There began the first period. The second period started after the 1960 year. Before the independence, the exploration works were realized in two stages from 1947 to 1957 and from 1958 to 1961. The first stage regarded the recognizing of uranium occurrences in the magmatic and pegmatitic formations. For this, three missions were organized in the east of the CAR. The first mission took place from March to July 1947. The second mission was realized from April to June 1949, and the third mission from November to April 1956. The second stage had concerned the uranium research in sedimentary basins by the prospecting Mbaïki Series (January 1958-January 1960) and Fouroumbala Series (August 1959-June 1961). These series offered the chance to CEA to discover the Bakouma uranium deposits. After this discovery in 1965, the falls of prices of the uranium provoked altered stoppings and resumptions of works with the following societies: the Company of uranium ores of Bakouma (URBA) 1969; Centralafrican uranium (URCA) in 1975 but dissolved in 1981; in 1989-1991, the Japanese Nuclear Power Corporation (PNC) for a deposit re-examination; URAMIN Centrafrique in 2004-2005 and AREVA Resources Centrafrique in 2007. The last-mentioned had stopped works since 2012.

Key words: Uranium, exploration history, Bakouma uranium deposit, Central African Republic, URCA.

1. Introduction

The Technical Meeting on Uranium from Unconventional Resources in Vienna, Austria of 4-7 November 2014 offered me the opportunity in its objectives to write this paper which has for title, “The Uranium exploration history of the Central African Republic (CAR)”. Thanks to an historical recall of the U exploration [11], we can identify ores which were abandoned because the means of works at this time were weak. It will be possible to resume these works in the goal to discover new resources. Two chapters compose the paper. The chapter one carries on the exploration works before the independence. These works were realized from the period of 1947-1957 and the period from January 1958 to January 1960 and from August 1959 to June 1961. A detailed case of a U exploration history concerning the unconventional uranium Pembella site had been displayed in this article in the aim of an illustration of the informations. The point of Pembella with its association uraninite, molybdenite, chalcopyrite, and pyrite is to be connected with a hydrothermal origin. The second chapter approaches the exploration works after discovering the Bakouma deposits. Six societies succeeded to work in the CAR. These ones were the Company of uranium ores of Bakouma (URBA) in 1969, the Centralafrican Uranium (URCA) from 1975 to 1981, the InterURCA Company, the Japanese Nuclear Power Corporation (PNC) from 1989-1991,

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Uramin Centrafrique in 2006-2007 and the Areva Resources Centrafrique (ARC) Society, in 2007.

2. The Exploration Works before the Independence

Before the independence of the ex-Oubangui-Chari territory, the actual Central African Republic, two stages succeed themselves during the exploration works.

2.1 The First Stage of Uranium Exploration Works in This Future CAR (1947-1957)

This stage includes the prospection in magmatic and pegmatitic formations. The type of resource which had been prospected during this period corresponds to two models M_1 and M_2: M_1 model—Shinkolobwe type in Kasai (formerly Katanga) in DRC corresponding to high temperature veins with several occurrences of uraninite, monazite, gold and copper selenide in a context of dolomitic shale of Precambrian to Cambrian age, with low metamorphic grade; M_2 model—Veins of medium to low temperature uranium associated with various sulphides hosted by granites [7].

What were the real conditions on the ground for exploration? Two major constraints: (1) the metallogenic knowledge is embryonic; (2) almost non-existent geological data. The exploration was oriented on pegmatite veins and alluvial deposits at that time.

Three missions were conducted by the French Atomic Energy Commission (CEA) and supported by the Geological Department of the Equatorial Africa [7].

2.1.1 First Mission from March to July 1947

The objectives were to prospect crystalline and metamorphic units, rich pegmatites in the region Bambari and alluvial concentrations for locating potential uranium occurrences and to determine the metallogenetic types to orientate future research. Alluvial prospection led to the discovery of presence of monazite and samarskite to the southeast of Ippy, whereas pegmatite prospection led to the identification of traces of uraninite near the center of the area.

No further exploration has been done since on these occurrences [7].

2.1.2 Second Mission from April to June 1949

The exploration program dedicated to gamma radiation survey. The exploration program dedicated to gamma radiation survey was initially concerning a large of the country. However, because of budget limitations, the study has been reduced to the Bambari-Alindao sector. It agrees that the CEA studied also alluvial concentrates for gold and diamond exploration in this region.

Further monazite occurrences have been discovered together with U and Th-rich niobo-tantalates in the Ippy area.

2.1.3 Third Mission from November to April 1956

Six years after the last mission, the prospector’s team of the CEA has been reinforced by geologists of the Service Géologique and the geological map has been developed by the National Geographic Institute (IGN). The objectives were still the prospection of granitic massifs in the same way as the previous exploration campaigns. Autunite occurrences were discovered in granitic massifs and pegmatites [7].

2.2 The Second Stage of Uranium Exploration Works in the CAR

The second stage had concerned the uranium research in sedimentary basins by the prospecting Mbaïki Series and Fouroumbala Series.

2.2.1 Sedimentary Basins Prospection

Uranium-bearing sedimentary basins of Witwatersrand type in South Africa and of Blind River in Canada have been looked for during two missions: the Mbaïki Series (from January 1958 to January 1960) and the Fouroumbala Series (from August 1959 to June 1961) [7].

The Mbaïki Series.

(a) Ground exploration using gamma radiation and water, soil, silt geochemistry and mapping over an area of 12,000 km^2 for a mesh of 5-20 km. Several radiometric anomalies were located in granitic gneisses (especially in the river Pembella, see the part 1.3 which evokes the site carrying the Pembella site), psammites, quartzites and shales of the Mbaïki Series. Anomalies related to Carnot sandstones were prospected in great detail, but the report of this prospection work was not discoverable.

The present paper takes back, on the paragraph 1.3, the report about the exploration of the unconventional uranium Pembella site.

(b) Airborne exploration by Air Corporation Mining Research (MRSA)

Airborne scintillometry led to the discovery of a large number of anomalies scattered throughout the area and has confirmed the zones where radioactive occurrences were formerly discovered by ground survey but has also highlighted the interest of other zones. The results have enabled at that time the development of methods for general radiometric airborne protection and of detailed ground exploration of uranium in tropical climates.

Fouroumbala Series (August 1959–June 1961).

(a) Ground exploration has covered 50,000 km^2 including the Fouroumbala Series, with the units of Banga, Tandja, Middle Chinko and Morkia, but also a part of the basement complex in the southern sandstone plateau (Mouka-Ouadda).

(b) General airborne exploration has been conducted by the SARM-ASMR (Société Aérienne de Recherche Minière-Aerial society of mining research). The lines of flight were orientated east-west and spaced of 1 km with an average altitude of 75 m. Numerous anomalous zones were identified, mostly in the basement Complex and some weak anomalies in the Mouka-Ouadda sandstones.

(c) Detailed airborne exploration has been done by the CEA (from September 1960 to May 1961) to define more precisely the anomalies discovered during the previous phase, between those which can be related to anomalous uranium concentration from those due to other causes. Most anomalies verified during this phase result from soil or lateritic crusts, with the anomalies almost all located at in the basement Complex. The anomalies were confirmed in the area of Nzako and Mpato.

(d) Ground check (1960-1961): Several anomalies have been controlled, those of the Nzako Valley (Ambilo zone) where the radioactivity and the uranium contents have been related to lateritization processes. No anomalies in the outcrops and the radioactivity decreases with depth; and those of the Mpato Valley where autunite mineralization and chalcolite in yellow more or less sandy clays, joints, drusy quartz cavities. The presence of higher uranium concentrations is suspected.

2.3 A Detailed Case of Historical Exploration: The Unconventional Uranium Pembella Site

This paragraph presents the geological framework of the Mbaïki Series in which have token form the uranium occurences of Pembella and the detailed exploration of an unconventional uranium occurrences: the Pembella site case.

2.3.1 The Mbaïki Series geological Framework

Bangoto and al. [1] report that from G & J. Gérard (1953), the Mbaïki series are composed of four features: the granitic gneisses (especially in the river Pembella), the psammites, the quartzites and the shales of the Mbaïki Series. In the north of Boda, G & J. Gérard (1953) [7] have described biotitic gneisses with microcline and oligoclase, including localy sillimanite, with inserted hornblended gneisses. They are in general concordant with the neighbouring formations and progressivly come to migmatised formations. Yet, the Mbaïki sector is in the South-east of Boda. We can deduce, on condition of verification on the land that these are same migmatised formations which extend the most in the South upon which the Pembela River flows [2].

G. and J. Gérard (1953) [7] indicate that among the migmatites, two facies differ: the embrechites and more rarely, the anatexites. The dominant feature is the one of embrechite which shows however a striped texture more irregular, heterogenous and locally nebulitic. At the microscope, the perthitic microcline appears in abundance, associated to the secondary quartz and embodying the residues of migmatites, rich like them, in secondary minerals, in particular sphene and allanite. The psammites do not be others than fine sandstones that we can find again sporadically in the banks situated above of the conglomeratic base of Carnot sandstones (in the CAR-West).

The aforesaid authors have observed quartzites, oriented North-west in the South of the Mbaïki-Boda road. The dominant facies is the one of sandstone-quartzite when the rock is slightly altered; but when it is healthy, it is compact with a quartzite aspect. At microscopic examination, the quartz grain appear with variable size, rounded, or with slightly jagged sides, sometimes joined in genuine quartzite, but the most often separated by a quartzo-phillitous. In this same sector, the conglomeratic quartzites are enough frequent.

Bangoto and al. [1] indicated that G. and J. Gérard (1953) [7] have noted the presence of rare phyllitous intercalations with sericite and chlorite. We are attempted to attribute the origin of the shales of the Mbaïki Serie to these alteration facies.

2.3.2 Exploration Works of an Unconventional Uranium Occurrences Site: The Pembella Site Case [8]

We use the report established by Morin N. (1959) [8]. This report retraces the geophysical campaign aim of the Pembella site, the duration and the statistics of the works and the general on the site.

The geophysical campaign aim and the duration. The first works following the discovery of the point to 2000 shocks aimed, the study of the very occurrence and of its possible extension. This point is marked 1,800 shocks on any plans but the 2,000 shocks measure was actually read to the probe GMT 14. The difference between 1,800 and 2,000 shocks exceeds only of few, the precision of the device. This report indicates that the occurence had itself no big interest but was decided a more detailed campaign of works. A mineralization uraninite sulphurized in a zone of migmatites is rather rare to justify a more thorough study.

This study had to come to an end in the delivery of the results of the air prospecting of the Series of Mbaïki, but it was extended until November 20th, 1959 for the exploitation of an important geochemical anomaly in grounds. She lasted 7 months from May 5th.

The statistics of the works. We remove the data relative to general services to preserve only those who concern the technical shutter of the works, in particular the radio prospected mileage and the number of swabs of geochemistry. For that purpose, 3 teams of prospecting were constituted as indicate it the table which follow. A total mileage which was radioprospected for the 3 teams was 483 km for 4,925 geochemical takings [8].

The question is to know if these measures are sufficient and good to allow getting acceptable results. It is important to consider it in the objectives of the 2014 URAM symposium such as providing information on geological models, new exploration concepts, knowledge and technologies that will potentially lead to the discovery and development of new uranium resources and describing new production technologies that have the potential to more efficiently and sustainably develop new uranium resources.

The number of the geochemical takings on the Pembella site. The same question like above is put because the objective is to have good information of confirmation of the existence occurrence with a quantity of geochemical data of a certain quality.

General on the Pembella site.

(a) Location

The studied zone is situated in approximately 80 km in the N-NW of Bangui. It is on horseback on the maps at the N-NW at in 200,000 scales of Bangui and

Table 1 Indicating the radio prospected mileage of the Pembella site [8].

	May	June	July	August	Sept.	October	Nov.	Total
Delaunay	31	40	13	22	23	20		149
Privat		26	30	35	39	40	26	196
Duneigre			29	36	30	30	13	138
Total	32	66	72	93	92	90	39	489

Table 2 Indicating the number of the geochemical takings on the Pembella site [8].

	May	June	July	August	September	October	November	Total
Delaunay	231	814	249	403	362	350		2,409
Privat		91	131	196	234	216		868
Duneigre			144	177	172	450	705	1,648
Total	231	905	524	776	768	1,016	705	4,925

Bogangolo. The center of this zone has boorishly for coordinates: X = 18°16' E, Y = 5° N. It is limited in the NE by the stream Mpoko, in the NW by Diéba, in the W by Ndogara stream and the upper course stream of Gbagbari, in the SE by the Dambou stream, in the E by a joining the Badele-Dambou confluence to the Pembella-Kougoulou confluence.

(b) Access

One goes on the sector by the road. There is 125 km which are relatively easy for an all-road vehicle. We borrow at first the road Bangui-Bouar up to 52 km then we turn northwards by the road of Kouzindoro. In the North of Kouzindoro, a runway of 23 km made by the CEA (Atomic Energy Commission) group takes to the Pembella occurence and continues on 2 km up to the river Lingoto.

(c) Hydrology

The sector is situated on the right bank of Mpoko, big right tributary of Oubangui. All the rivers of the studied zone are drained in Mpoko by Diéba, Lingoto, Pembella or Dambou. In dry season, these rivers are of not much importance and are even dry in their superior streams. In rainy season, the water is more plentiful but the debits remain weak. They are short rivers, some kilometers in length, with irregular stream and debit. The crossing of quartzite gives rise to numerous rapids or to small falls.

(d) Morphology

This region is constituted by a plateau falling regularly of the SW where the average height is 550 m to the NE where it reaches 420 m. The dullness of the plateau is broken by the ridges of quartzite directed NNW and who form rather abrupt lengthened cliffs. They peak in a little more than 600 m.

(e) Method of work

It consisted in making: (1) a detailed sunrise of the outcrops by becoming attached to the measure of the directions and pendages of the diaclases and plans of schistosity; (2) altimetric measures; (3) a continuous radio prospecting on parallel tailboards; (4) takings of grounds and alluviums for geologic study.

(f) Documentation

- Geology: Map in 200,000 of C. Bizard and map in 2,000,000 of Equatorial French Africa of the Direction of mines and geology (DMG) as well as some results unpublished of works itinerary of the DMG.
- Topography: The photos of the IGN (National Geographic Institute) in 50,000 and the photographic enlargements in 1/2,500.

Effected works on the Pembella site.

(a) Works of excavation

The 7 trenches were executed on the vein formation of the occurrence itself and 3 scratching on its extension.

(b) Systematic works

- Plan-meter: a plan-meter at the distance of 5 m was made around the occurrence for 2,000 shocks on a surface 18 ha.

- Geochemistry: on this surface, takings of geochemistry were made for the stitch of 20 m.

Finally, in the North part, the systematic works were made around an anomaly for 93 ppm in a taking made in a swampy zone.

(c) Works detailed in the stitch (maille in french) of 50 m

In extension around the plan-meter, a radio continuous prospecting was made on tailboards distant from 50 m and takings of grounds were made for the square stitch of 50 m. And 650 ha were so covered. After the stage of the works in the stitch of 200 m, a radio continuous prospecting in the stitch of 50 m was made on a zone where the results of geochemistry and the radioactivity offered most anomalies. This zone is situated between the springs of Kougoulou, the Bongo drum and Pembella 92 ha of flatware.

(d) Works detailed in the stitch of 200 m

These works of exploitation included a continuous radio prospecting of parallel tailboards distant from 200 m and from takings of grounds in the square mesh of 200 m. By ending on this part relative to the works made on the site of Pembella, Morin N.[8] insists on the choice of the period of the year the best indicated for field works. In rainy season, the plant place setting is more important and the big floods of streams mask all which is outcrop. The dry season which increases of at least 3 times the working yield is the period the best indicated for the campaigns of ground.

Documents on the Pembella site. The documents and archives gathering was done on the following way: (1) geological routes of 3 leaders of columns containing the detailed description of 1,323 outcrops; (2) a report of the end of sector for every column including the following maps in 5,000 or 12,500; (3) altimetric map; (4) outcrop map carrying the numbers of outcrops corresponding to the descriptions of the exercise books of geological routes; (5) location map of the takings of geochemistry; (6) map of interpretation of the results of the takings of grounds; (7) map of interpretation of the results of the takings of alluviums; (8) map of radio prospecting and of radioactivity; (9) geological map; (10) map of diaclases and schistosity plans ; (11) larger-scale plans in 20,000 for the systematic works: plans-meters, excavations, works on anomalies.

2.3.3 Obtained Results of Exploration Works on the Pembella Case [8].

The Morin report presented first, the results relative to Pembella occurrence and after, those concerning the whole of this site [8].

Obtained results on the Pembella occurrence. The results were obtained from studies in trenches, on the map-recorder and the geochemistry.

(a) Trenches

Geology. The mineralized point of Pembella is situated in a vein zone constituted by crushed gneiss and resilicified by rusty and smoky quartz. This zone in trenches was followed on 23 m. It is very irregular in thickness and in direction; it presents even some digitations of very weak extension. The encaissante rock is a migmatitic gneiss which constitutes the main part of the rocks of this region. The direction of the vein zone varies of N-S to N 30° E. It presents uncouplings in staircase. The pendage is not observable. The power varies 0.10 m in 1.30 m. The uraniferous mineralization is established by the uraninite in small crystals of squared section reaching 1/10 of mm^2, of the parsonsite, the gummite and maybe the kasolite. The uraninite is slightly thoriferous, it contains 0.5% of thorium. Finally in uraniferous minerals, it is necessary to quote the monazite, the content of which U is 0.3% in samples taken from the occurence. To these uraniferous minerals are added pyrite, chalcopyrite, covelline, galena, molybdenite. Contents U were made on samples which had been selected for their strong radioactivity to facilitate the study of the mineralization. The takings made in such conditions gave contents from 0.1 to 0.4% of U. It is likely that if we had made the systematic takings, all the meters, perpendicularly for the vein zone and on all its power, some takings only would have been uraniferous and the richest would have a content certainly lower than 1 for 10,000 (1/10,000). To fix the ideas, let us say that during our investigations on the occurrence, the total quantity of uranium which we met is of the order of the decagram.

Radioactivity (see board n° 3 in the 100th). The radioactivity in trenches exceeds 100 shocks on the vein zone on a length of 23 m. The maximum measured on this zone varies from 1,800 to 2,000 shocks according to the used device. A vein digitation near the scratching G-2 gives radioactivities from 600 to 1,500 shocks. The radioactivity is confidentially connected to the vein structure and decreases as soon as we go away from this one.

(b) Map-recorder (see board n° 4 in the 400th)

The plan-meter made around the occurrence showed only a very weak spot around this one and 2 other weak anomalies corresponding to activities on outcrop.

(c) Geochemistry (see board n° 5 in the 500th)

The results of geochemistry show that the regional bottom is strong. The majority of the takings have a content superior to 4 ppm. The point corresponds itself to a spot with strong content, superior to 9 ppm. The point to 288 ppm corresponds to a taking made after the first works of excavation and this content is due to the contamination. Downstream to 14 ppm, finally in 200 m in North-East of the trenches, a zone superior to 9 ppm appears.

(d) Conclusion

From June, the systematic works on the very occurrence were stopped. The pursuit of the investigation would have asked for the other more important resources than the value of the occurrence did not justify.

Obtained results on the whole of this site.

These results cover the geological, geophysical and geochemical aspects.

(a) The geology

Here is described the petrography, the mineralization and the tectonics of the study sector. It is certain that it will be on these elements of geology that possible works of complementary investigations could take place.

Board n° 6: Geological map and board n° 7, Takings map.

Petrography

- Granitised gneiss or migmatitic gneiss. This rock forms the largest part of the studied zone. It has very different facies varying of grainy granite almost without orientation in normal gneiss or in facies presenting all the metasomatic aspects: anatexite facies, embrechite facies, and heterogeneous migmatite facies. In the outcrop, we observe most of the time gneiss in biotite in unpolished schistosity crossed by past quartzo-feldspathiques arranged according to plans most of the time parallel, sometimes any. Thickness: 1-2 m, spacing: some decimeters a few meters away. They constitute a contribution cutting clearly on the bottom, what justifies the term of migmatite heterogeneous. The microscopic study of numerous samples gives the following results: (1) In the majority of the cases, the structure is grainy and cataclastic, we do not find in the microscope, the structure of gneiss; (2) Essential minerals are: quartz, plagioclase and biotite. The plagioclase is nearby of the andesine, it is most of the time, the only feldspar. Sometimes, the microcline appears next to the plagioclase but always in lesser importance. Finally some samples showed the presence of muscovite; (3) The most frequent secondary minerals are: zircon épidote and zoïsite.

The composition of the rock reminds that of the diorite quartzique with sometimes, passage in a composition of calco-alkaline granite when the microcline is present.

Through this group, zones of several hectares are loaded amphiboles there, enough so that we can give to the rock, the name of gneiss in amphibole. More rarely and more locally, garnets developed inside gneisses. The cataclastic structure reproduces the history of the strong pressures which underwent the rock at the moment or shortly before or after the migmatisation.

- Quartzic microgranodiorite. Some isolated outcrops in very particular aspect remind in a macroscopic manner a micrograiny rock. The examination in thin blade gives the following results: rock with micrograiny porphyric structure, phenocristals: damouritised plagioclase, aphanitic dough: quartz, feldspar, biotite, additionally epidote.
- Quartzites. They come in importance, in the studied zone, immediately after the migmatites. They form directed ridges N in N 30° W. Quartzites appears under 3 different facies:

  --Ferruginous Quartzites. It is the most important. They contain in strong proportion, of the oligiste and in lesser abundance and less regularly some magnetite. The oligiste is either, confidentially involved with the rock giving him a tint brown-darkened, or separated in beds parallel and calling back then itabirites.

  --True Quartzites. They are of clear, very yellowish tint, an important part of the outcrops is constituted by a quartzite very evolved, transformed into hialin quartz in fat brightness.

  --Quartzites with minerals: quartzites often contains of the sericite. More rarely, they contain crystals of tremolite or garnet.
- Amphibolites. They are essentially constituted by andesine and by hornblende. They always contain the pidote as the secondary mineral. The biotite is there almost constant; finally the garnet is there frequent. Amphibolites constitute a set of well aligned outcrops, especially in the North of the sector.
- Amphiboloschistes. The outcrops are rare. We have then a rock with nematoblastic structure whose bottom is formed by quartz and of tremolite. The plentiful oligiste is confidentially connected to the other minerals.
- Micaschists. They are rare and form only thin crossed in gneisses, without extension and without report between them. They are constituted by a matrix of muscovite and little of biotite in which restarted some nodules of quartz.

<u>Mineralization</u>

Oligiste: Constituent importing quartzites, so present in gneisses near the contact with quartzites. Magnetite: observed in quartzites and indicated in certain samples of gneiss. Pyrite: observed in gneisses, quartzites and in some samples of amphibolites. Chalcopyrite and cubanite: these minerals were indicated in the samples of migmatitic gneiss taken in the joining of rivers Kangabélé and Lingoto. Outside its radioactivity, the outcrop presented no peculiarity, either quartz, or presence of any vein formation.

<u>Tectonics</u>

The observations on the ground were specially managed towards the search for accidents possible which would have been able to guide in the prospecting or to bring an interest additional in this region. No observation revealed the existence of fault or of important tectonics which can favor the implementation of a mineralization. Some outcrops with big development of micas which had been able to be considered as indications of accidents showed, in the microscope that it is about mica-schist in whom quartz were perfectly intact. Aerial photos show some privileged directions, but, on the ground, none tectonic explanation was found. On the other hand, corresponding ridge lines in quartzite find and explain very well by a simple difference of hardness in the erosion. Diaclases were measured. The transfer of all these directions on the map in 20.000 shows the following measures: N°290, N°50, NS. The measure of the plans of foliation of gneisses, mutual arrangement of the plans of foliation of the outcrops of gneiss and quartzite show a perfect concordance between these diverse elements. These directions vary generally between N 30° W and NS. The plans of foliation are vertical to sub-vertical in the center of the sector. They have a fort pendage in W and a fort pendage in E.

No stratification which can remind the old sedimentary formation which gave birth to it, was not observed in this series. Also, the contact gneiss-quartzite was not able to be observed in rather good conditions to deduct from it from a way absolved, the positions reverse of rocks. At the most, we can assert that these individualities belong in it even serial because we observed the interpenetration of migmatites in quartzite in the river Pembella in some hundred meters downstream to the occurrence.

For lack of more characteristic observation, we can nevertheless suppose that the plans of foliation of gneisses correspond to the old stratification. The old formation would take then the shape of a pinched syncline, the quartzite having resisted in the axial part of the syncline.

Relations of the diverse rocks between them and geologic history [8]

All the rocks of this zone belong to the lower antecambrian. Their history seems simple. There was at first in this region, a pond of sedimentation formed essentially of clayey pelites with lateral sandy passages and some calcareous formations. The pond of sedimentation buried itself profoundly, there was wrinkling and metamorphism. Pelites gave by metamorphism, gneisses. Pure sandstone gave true quartzites. Ferruginous sandstones gave quartzites to oligiste. Then, calcareous zones brought development of amphiboles in quartzites and gneisses. Finally, the migmatisation has penetrated the group, coming to stumble over quarztzites, the migmatisation came along of one strong cataclase whose tracks appear to the microscope. The outcrops although intermittent are aligned well and recut frankly the directions of gneisses and of quarztites. We consider them as the product of metamorphism of basic eruptive rocks which had crossed the old sedimentary series.

This group had its history stopped in the antecambrian period and has undergone since the effect of the erosion and the pressures the only appearance of which is the presence of diaclases. He can exist very local accidents of the type of the occurrence of Pembella, they escape then the surface observations, but there is not in the sector studied an important fracture. We note the phenomenon of lateritization there.

(b) Radioactivity

Supports are the map of radioactivity (see board n° 9) and the map of radio prospecting (see the board n° 10). The appropriate movements of quartzites are of the order of 1,520 shocks. Migmatitic gneisses are more active and, according to zones, the appropriate movement varies from 25 to 30 shocks and from 35 to 50 shocks. Finally, certain zones with lateritic covering have an activity varying from 50 to 60 shocks. All in all, except the occurrence itself, it discovered 14 points equal or superior to 100 shocks among which one-200 shocks. All these points were found on outcrops of migmatitic gneiss in which one nothing particular appears. The chromatography indicates traces of U, on the other hand, on several samples; the examination in the laboratory indicates that the radioactivity is especially due “to the monazite and to the adsorption of Th by the altered ferruginous parts”. The sample 2,976 indicates 0.02% content there U and the presence of thoriferous uraninite and monazite.

In summary, the radio prospecting did not bring to the discovery of new indications and tends to show that there is in the migmatitic gneiss of the zones more loaded U and Th, these zones explain the anomalies of activities, geochemistry, the air anomalies do not constitute deposits. It is necessary to add that the thickness of covering decreases considerably the possibilities of the radio prospecting method. In particular, such an occurrence as that of Pembella would not have been found less than 2 m of covering. On the other hand, a powerful and rich vein it uraninite under 2 m of covering would have been discovered by the products of change which would have scattered in grounds.

In the case of a work restricted upon a point of big interest, the use of the auger and the probe GMT 14 allows to increase our means of investigation in considerable proportions.

(c) Geochemistry

The map of geochemistry of grounds (board n° 11), the map of geochemistry of alluviums (board 12) and the altimetric map (board n° 13) were of use as support to the works of geochemistry. The results of grounds showed that the studied region had a strong geochemical content. Except little in the East and in the South, our works bounded this region with strong content and reveal outside, a regional bottom lower than 3 ppm.

The zone with strong content (superior to 3 ppm) is directed NW-SE, it presents a block to the NW and a block in the separated in the center by a narrow lane. These blocks include wide spots superior to 6 ppm, some isolated spots superior to 10 ppm and some points superior to 14 ppm of which a point to 63 ppm which was the object of more detailed works. Spots superior to 6 ppm reflect on the West part, the head office of the zone, always on this West part, the isolated spots superior to 10 ppm are also aligned in a parallel to this direction.

The Pembella occurrence forms a slender zone superior to 6 ppm with some points superior to 10, situated in the lane separating 2 blocks.

Interpretation

At first, it is to notice that geologically, the zone with strong content aligns itself well enough with the contact quartzite-gneiss and that is situated on the quartzites west, it thus seems bound to migmatitic gneisses. Also, although is badly known the progress of waters near the surface and the dispersal of the uranium in grounds, the massive forms of zones superior to 3 ppm and 6 ppm incite to think that they are more due to a weak U impregnation, of a mass of gneiss directed NW-SE than in an uraniferous concentration.

On the other part, if are considered only spots superior to 10 ppm (and it is the way of approaching the closer the truth), they align themselves well enough and could represent a vein appreciably parallel to the runway, extending of the river Ndagara in the NW to pass by the springs of Lingoto, Pembella and end in the SE by the ridge line situated between the springs of oxbow lakes Badélé and Boaha and the upper course of Dambou. We could imagine that the central part of this vein would be picked up towards the NE between 2 faults; this part would correspond to the corridor lane formed by the spot of Pembella. But this hypothesis is not enough supported to allow to make on this imagined vein, 2 drillings in cross.

The geochemistry of alluviums reflects partially that of grounds. What is to retain some comparison of grounds and alluviums is that the latter give an image shaded off by the U content, they integrate in a way the U contents of the entire versant basin and give only regional indications. They are thus of a big utility in the general recognition. The discovery of a point to 93 ppp at the spring of the first one straight streaming ahead of Lingoto after Kambalélé brought to make more detailed works. Takings of ground in the stitch of 20 m were made around the point on a surface of 4 ha; near the point, takings of control were made in the stitch of 5 m. Disappointing results: 5 takings superior to 20 and a set between 6 and 10 ppm with some small spots superior to 10 ppm. Trenches were made. The bed-rock is made by gneiss; the radioactivity does not increase in depth. The radio prospecting made for the stitch of 20 m on a surface of 5 ha indicates on the ground a clean movement of 20 shocks, on the outcrops of gneiss a clean movement of 30 shocks in 33 shocks with 2 isolated points, one-40 shocks, the other one to 48. This point was abandoned. This zone has to correspond to a content U maybe a little higher of the gneisses and the point to 93 ppm is due to probably very local physico-chemical conditions which we do not know how to explain and which brought this concentration. It is necessary to recognize that it is the very superficial explanation there and that the example of this point to 93 ppm is typical of our current incapacity of interpretation in a satisfactory way the results of geochemistry.

Conclusion on the obtained results on the whole of the Pembella site. The point of Pembella with its association uraninite, molybdenite, chalcopyrite, pyrite is to be connected with a hydrothermal origin. It does not constitute a deposit and in the eyes of the classic economic geology, the region seems little favorable. If on the other hand we refer to the only facts there, the results of geochemistry and radioactivity demonstrate the existence of a vast massif soaked of U. We can think: (1) or that this U is in inclusion in the rock, in which case the region is without interest if there was not a secondary concentration; (2) or that this impregnation is due to the dispersal from an important primary concentration which could constitute a deposit. Nothing allows stopping definitively in one of these hypotheses, anyway, none of it excludes the existence of a deposit.

It did not found a deposit but we cannot say that it does not exist there. If they exist there, they escaped our means of investigation. We can consider that if similar zones present in the future, of the interest in other regions and if our means strengthen, the study of the sector of Pembella could be resumed. The following articles which were presented during the works of the URAM 2014 symposium in Vienna confirm theses words of Morin N., 1959 [8]. These ones were: “Uranium exploration (2004-2014): New discoveries, new resources” of Polak C. [9], “Felsic magmatism and uranium deposits” of Cuney M. [3], “Granite-related hypothermal uranium mineralization in South China” of Liu X. [5], “Recent advances about the unconformity-related U deposits” of Mercardier J. [6] and “Basement to surface expressions of deep mineralization and refinement of critical factors leading to the formation of unconformity-related uranium deposits” of POTTER E [10].

Morin N. [8] brings reports that he is good after such a study, to review what every method brought. The radio prospecting gave a set of active points without big meaning which shows that the region contains. The geochemistry brought additional details; she specified sets more uraniferous and had restricted the problem. It is unmistakably a deeper means of investigation. Within the framework of this study, it seems that the limit of these means was reached and a more powerful means would have been wished: it is a small drilling machine on car which would allow to drill holes of 30 m then do radiocore drilling after examinations of their cuttings for, in favorable cases, finding deposits buried in about ten or about twenty meters.

2.4 Partially Conclusion

Before the independence of the country, both stages of research for uranium had taken place successively in the magmatic and pegmatitic formations and in the sedimentary formations. In the magmatic formations, the researchers did not end in indications which can prove the continuation of the works as there were the cases for the works of exploration in the sedimentary series. In the sedimentary series, the formations of Fouroumbala presented several anomalies in the valley of Mpato. The presence of high concentrations of uranium was suspected. A mineralization of autunite and chalcolite was revealing from the works on the ground. The site of Pembella is in a hydrothermal context but did not allow the discovery of deposit, as concludes it Morin N. in its report. By questioning totally the weak performance of technological means used at this time, this author moves away any link between this non-discovery of deposit and its nonexistence. He proposes, and what is logical, the resumption of the study of the site of Pembella, but also that of the magmatic and pegmatitic formations the discovered in the country, by basing itself on results obtained in similar zones with much more developed means. The symposium URAM 2014 was a receptacle of information sources which can serve as bibliographical support for the possible resumption of the works for the research for these new resources U non-conventional.

3. The Exploration Works after Discovering the Bakouma Deposit

In this part, were be presented the creation of the Company of uranium ores of Bakouma (URBA) in 1969, the Centralafrican Uranium (URCA) from 1975 to 1981, the InterURCA Company, the Japanese Nuclear Power Corporation (PNC) from 1989-1991, Uramin Centrafrique in 2006-2007 and Areva Resources Centrafrique in 2007.

3.1 The Creation of the Company of Uranium Ores of Bakouma (URBA) in 1969

The report of feasibility of the Company URBA in 1977 concludes the sub-paragraph “Mining industry” in the following terms: the exploitation of site will place the uranium in the front row produce of export of the Central African Empire and will certainly encourage other companies to look for and to exploit this metal in all the country. [14]

3.1.1 The Company of Mines of Uranium Ores of Bakouma (URBA)

In 1963, a Syndicate is formed by the CEA (Atomic Energy Commission) and the French Company of the Ores of Uranium (CFMU) and had to demonstrate the existence of a deposit of uranium in the region of Bakouma as well as that of a deposit of brown coals to Nzako near Bakouma. It is April 29th, 1969 when this Syndicate is going to join in the Central African Republic to constitute the Company of the Mines of Uranium of Bakouma (URBA). Works of radiocores drilling were made and led to the following results: three mineralized bodies highlighted from the data of the check on the ground in 1961 and one deposit of brown coal in 1967. The feasibility study demonstrated that the deposit was not mineable in the market conditions of this period. The Central African Government looked for then with the agreement of his partners of the URBA, other susceptible companies by their technological or financial contribution, to contribute to the development of the deposit. Swiss aluminum (ALUSUISSE) agreed, in January 1974, to be interested in the business and began for those purpose new studies.

3.2 The Centralafrican Uranium (URCA) from 1975 to 1981

The Company of the Central African Uranium URCA was based legally on June 11th, 1975. His object is the study and the exploitation of the deposits of U of Bakouma and brown coals of Nzako. The initial share capital, of 45.000.000 F CFA, is distributed in the following way: Central African Empire: 33 1/3 %, ALUSUISSE: 33 1/3 %, CEA: 16 2/3 %, CFMU: 16 2/3 %. In 1976, the CEA transferred all of its actions to its wholly-owned subsidiary, the Company of the Nuclear Materials—COGEMA [14]

3.3 InterURCA Company

The partners of URCA agreed to create in Zurich, in 30 days following the putting in exploitation of the deposit of uranium of Bakouma, a limited company of Swiss right, which will call “InterURCA limited company”. The object of this company will be the marketing of the uranium produced by URCA on steps world. The social capital of InterURCA, fixed to 90.000 Swiss francs, will have restarted at the rate of: 33 1/3 % in the Central African State, 33 1/3 % to Alusuisse, 16 2/3 % to the CEA (Atomic Energy Commission) and 16 2/3 % in the CFMU. URCA will grant to InterURCA the exclusivity of the sales of uranium. These will be made in so advantageous conditions that possible, for a 5% sales commission calculated on the value of the trade products, depart factory of concentration. InterURCA will grant a right of option on the URCA production at the world price to Alusuisse for 50% and to CEA for 50% [14].

Table 3 Summary of the drilling of reconnaissance realized in the basin realized in the basin of Bakouma (non-included general exploration)-[14].

		Meters		
		Meters of coring	Radio-coring	Total
Pato	CEA-CFMU	3,446.5	3,320.5	6,767.0
	Alusuisse	838.6		838.6
	Total	4,285.1	3,320.5	7,605.6
Patricia	CEA-CFMU	59.4	5,949.3	6,008.7
	Alusuisse	2,027.4	1,539.7	3,567.1
	Total	2,086.8	7,489.0	9,575.8
Pama	CEA-CFMU	620.4	12,224.2	12,844.6
	Alusuisse	490.5	408.8	899.3
	Total	1,110.9	12,633.0	13,743.9
Divers	CEA-CFMU	≈ 500.0	≈ 14,771.0	15,271.0
	Alusuisse	258.8	912.7	1,171.5
	Total	758.8	5,683.7	16,442.5

Table 4 Mineable reserves of the Bakouma Project Reported by PRNFD in 1991 [10].

Deposit	Average content (% U)	Uranium soluble reserve (Tons of U)
Pato	0.275	843
Patricia North	0.284	2,346
Patricia South	0.187	672
Pama	0.193	819
Total	0.244	4,681

3.4 The Japanese Nuclear Power Corporation (PNC) from 1989-1991

In 1989, a Japanese State-owned company, the Power Reactor and Nuclear Fuel Development Corporation (Japan) (“PRNFD”), initiated exploration work that continued for two years.

In 1991 PRNFD undertook a feasibility study of the Bakouma deposit and determined the mineable reserves of near surface “soluble” ore (see Table 4). The term “Reserve” used in this report may not reflect the current meaning of the word in the CIM Definition Standard. On the basis of high production costs associated with selective mining within the “soluble” ore reserve, and the technical difficulties associated with development of a new metallurgical method to extract the “soluble” ore reserve, PRNFD concluded that economically feasible mining of the Bakouma deposit would be too difficult and terminated the project in 1991 [12].

3.5 Uramin Centrafrique in 2006-2007

The Bakouma Project is located in the Bakouma Basin, 110 km north of Bangassou in the Central African Republic. UraMin Centrafrique, a 90% owned subsidiary of UraMin Inc, has acquired a 100% interest in two mineral exploration-exploitation licenses over the project area for an investment of US$27 million, including exploration commitments to be applied over a twelve month period. The remaining 10% interest is a free-carried interest held by the State. The Bakouma Project consists of ten documented uranium deposits in close proximatly to one another. A synthesis of historical reporting indicates a target of 41 Mlbs U_3O_8. Previous work on the project in the late 1970s will allow the company to fast track the preparation of its own Definitive Feasibility Study (DFS) which commenced in January 2007. Preparatory work includes confirmation drilling, metallurgical process options and possible strike extensions. UraMin’s initial operations commenced in the CAR in May 2006, both at site and in Bangui, the country's. GRD Minproc (Pty) Ltd. has been appointed to undertake consulting and engineering services for the completion of the DFS. Environmental baseline work is already underway and 14,000 metres of RC drilling have been completed since August 2006. DFS is scheduled for completion mid-2008 and, should results be positive, commencement of mining activity is planned for late 2009/early 2010, ahead of UraMin's previous target for commencement of production at Bakouma. A letter of intent has already been signed in respect of electricity supply for the project [13].

3.6 Areva Resources Centrafrique in 2007

By a takeover bid, the licence of UraMin Centrafrique was acquired by AREVA Resources the Centrafrique. According to the indications of Henri de Dinechin, Chairman and Chief Executive Officer of AREVA Ressources the Centrafrique, UraMin Centrafrique is a subsidiary of UraMin Inc. One of its miners assets is constituted by the present deposits of uranium in the region of Bakouma. This transaction was made to allow the company UraMin Inc. to be completely a member of the group AREVA world number one in the nuclear energy. This integration within the group AREVA immediately materialized by the strengthening of the activities led in the country in particular by the recruitment of the staff and the affectation of the additional ways means in the field of the exploration and of it looked for by deposits of uranium. UraMin Centrafrique strengthens its identity and asserts himself as a full entity of the group AREVA. It was decided at the beginning of the year, following the example of what was made in other countries of the African continent (Namibia, South Africa, Senegal), adapt the trade name of this entity to the reality of ground. UraMin Centrafrique thus naturally became AREVA Centrafrique [4].

3.7 Partially Conclusion

The companies of research for uranium installed in Central African Republic saw each other quite affected in their functioning by two technico-economic factors. They are the parameters bound to the deposit and the course of the uranium on the world market. The sociopolitical criterion did not too much work in favor of the closure or the suspension of the works of these companies. The suspension of the activities of Areva Ressources Centrafrique intervened shortly before the sociopolitical disorders arisen in Central African Republic, but especially for reasons of the market of the uranium.

4. General Conclusion

The U exploration works history seems an inventory of occurrences of mineralization. It remains to mobilize appropriate services and expertise and modern technologies for the resumption of these important works which were abandoned. Because according to the last studies, it is planned that the demand will exceed widely the offer again very soon, efforts towards a comprehensive estimation of uranium from unconventional sources will provide important inputs to long-term nuclear fuel cycle supply. It will be necessary to classify the different deposits which were discovered. In the Session 3 of the URAM Symposium 2014, we speak about "Education and training in uranium production cycle". When different activities of academic researches upon the unconventional U exploration projects will start, we will also speak about "Education, training and human resource development in unconventional U exploration". Such projects will be inserted in national programs of the IAEA activities in the member countries. New vision calls new strategies.

Like that, these new discoveries in the CAR will be accounted between the fifteen deposits have been retained in the new IAEA international classification scheme and will complete the 1,525 uranium deposits listed in the database [2].

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