LITHO-STRUCTURAL AND PALEOGEOGRAPHIC ANALYZES OF THE SEDIMENTARY FORMATIONS OF THE SAKOA SERIES OF THE KARROO SYSTEM IN THE MORONDAVA BASIN.

A.C RAVOLAHY[1]

[1] *Arvel Christoph RAVOLAHY,* [2]*Vololonirina RASOAMALALA, Department of, Mineral Resource Management and Valorisation, University of Antsiranana, MADAGASCAR*

Various geological, geophysical studies and investigatings and as well as drilling in the Karroo sedimentary bed, particulary in the Sakoa series have been carried out for a century in the pits in the southern part of the Morondava basin.By geological analogy, the Mozambican sedimentary coast is formed with the same tectono-paleogeographic conditions and lithologic composition of the Malagasy sedimentary deposits.To this end, our study based on the analyzes of the formations, linked with different tectono-stratigraphic and structural or tectonic diformations, while taking into account of their lithologic compositions and their stratigraphies and especially their paléogéographic conditions during the accumulation of the deposits, the dating of formations, the presence of the organic, microbiological and biochemical substances and the possibility of the petroleum systems, can batter justify better and support the distribution of the structural areas and formations susceptile to oil and gas deposits or traps. The method known as" litho-structural and paléogéographic analyzesof the formations" is used above all during regional investigations; they make it possible to better to orient the detailed exploration work and to identify horizontally and in vertically all the formations or sub-formations in the tectono-stratigraphic and structural or in well defined structural zones.

Keyword: *Formation, Sub-formation, Litho-structural, Tectono – stratigraphic, Litho-paleogeographic, Structural zone, Petroleum system, Glacial tillitic,*

---

1. INTRODUCTION.

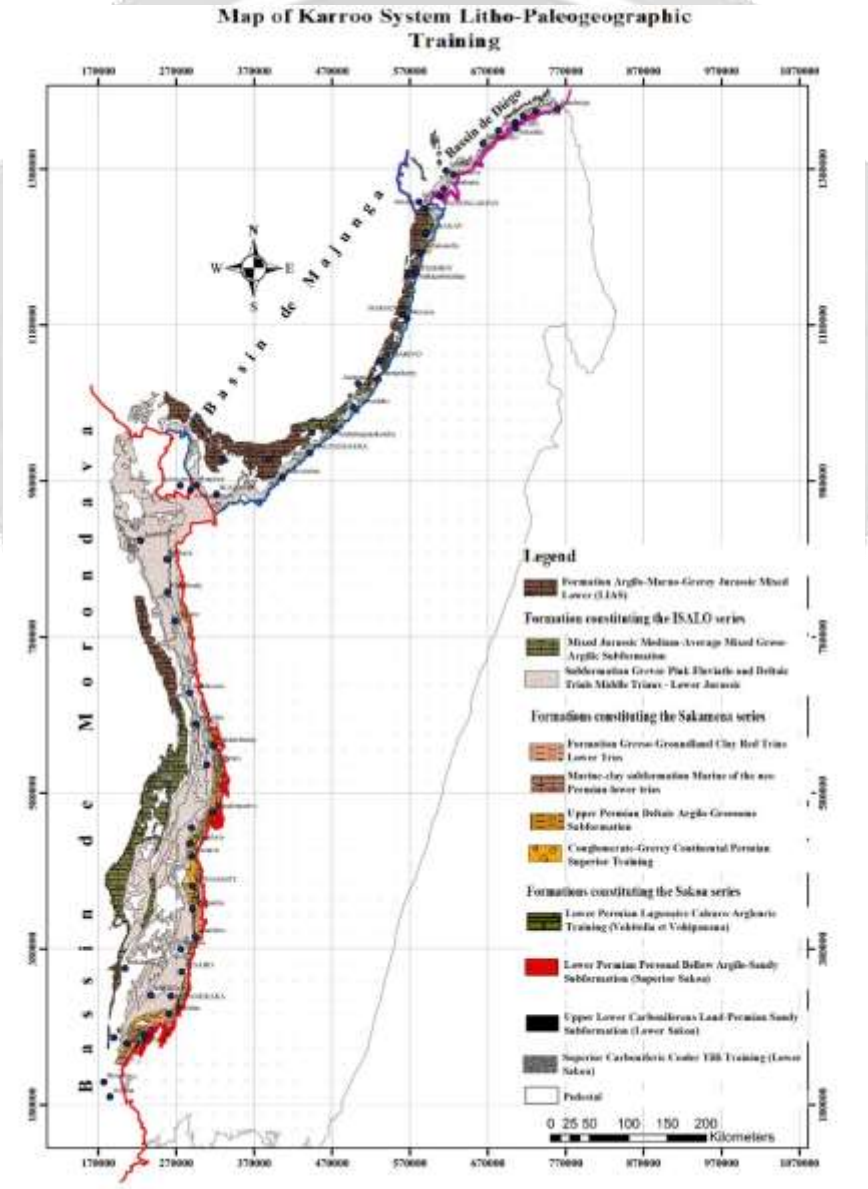
One of the concerns and desires of the Malagasy State is to discover deposits of oil or gas or condensate gas in the Sakoa series, located in the southern part of the Morondava sedimentary basin.

This article is part of the prospecting and the investigation of oil and gas deposits in the Malagasy sedimentary basins. In this article, a less expensive and rarely used but efficient method is proposed for the regional investigation of oil and gas or fossil coal deposits in Madagascar. Itmakes it possible to identify the formations or sub-formations vertically and the structural zones horizontally, the shapes of the geological bodies such as tabular layers, the reefs, the diapirs folds, the mouth bars, the lithologic bevels with their respectivelithologic composition, to identify their paléogéographic conditionsduring the accumulation of the deposits, their dating of formations, the presence of the organic, microbiological and biochemical substances and to identify the possibility of the petroleum systems or even any natural reservoirs with tectonic, stratigraphic and lithologic barriers likely to trap oil and gas or other fossil substances.

2. MATERIAL AND METHODS

2.1. Material

The lithological section obtained from the drilling are used to be correlated determining the shape of the body of the formations or sub - formations and for the establishing the distribution scheme of the natural reservoirs or the petroleum system. The formations in the Karroo system which date from the Upper Carbonaceous to the Lower Jurassic were identified from data from 55 boreholesdrilled by SPM, CHEVRON, CONACO, COPETMA, MOBIL, AGIP,OCCIDENTAL, AMOCO, OMNIS and other companies, located in the three large Malagasy sedimentary basins. The term Karroo encompasses sedimentary and intrusives formations, deposited or emplaced in Africa, in intra and peri-continental basins located south of the Equator. They are: the Karroo basin (South Africa), the Etjo basin (Botswana), the Limpopo basins and the Zambezi basins (Zimbabwe, Mozambique), the Congo basin (Zaire), the Rovuma valley (Tanzania), the Mombasa basin (Kenya), the Morondava and Majunga-Diego basins (Madagascar). In particular in Madagascar, the "Malagasy Karroo" has been recognized from oldest to most recent, having as series: Sakoa (UpperCarbonaceous - lower Permian), Sakamena (Upper Permian - Lower Triassic) and Isalo (Upper Triassic–Lower Jurassic). Each series is formed by specific geological bodies.



Map-1: Karroo system litho-paleogeographic of Madagascar

2. Methods.

The general principle of the practiced method consists in releasing a geological body called" Formation or Sub - formation "wich is different from the understanding of the" facies ".

Characteristic of the formations and sub - formations.

The meaning of the term "formation" is wide, different and depends on the definition given by the researchers.

In this article, a formation is a concrete geological body, delimited by the homogeneity of hislithological composition formed underwell - defined paléotéctonicsand paléogéographics conditions and corresponding to stratigraphic stages or seriesor rarely to a few series or part of a stage.

The analysis of the characteristic of Paleozoic, mesozoïc, cenozoïcsedimentary formations of the western coast of Madagascar make it possible to betterclarify, each formation released in the structural areas corresponding to it, the following points:

- Determination of the common lithological composition, the shape of the body occupying the surface, the thickness, the types of the main and secondary rocks, the change in their lithological composing and grouping in profile,
- Restoration of the paléotectonic, facial - paléogéographic, géochimical conditions of formations and their evolution.
- Description of the characters of the areas characters.

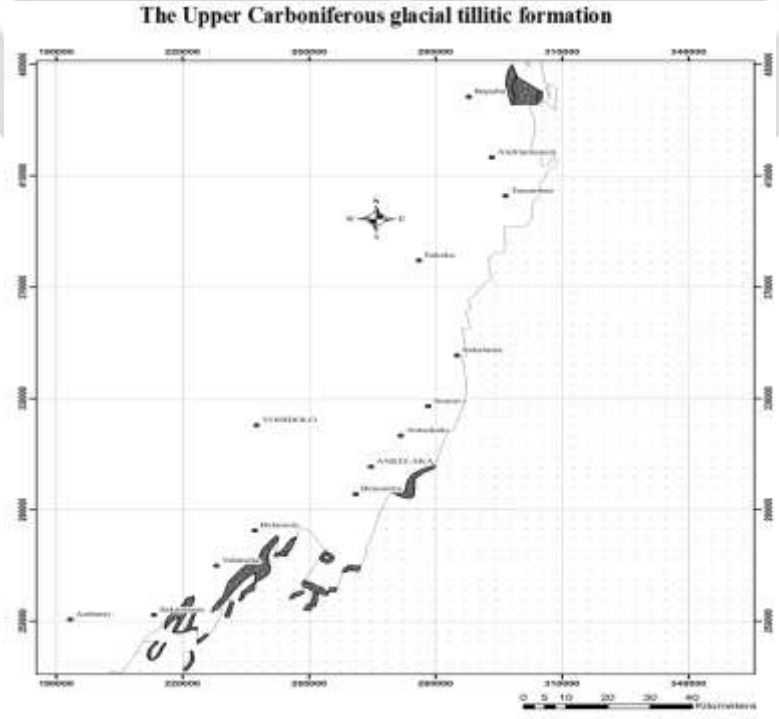
3. RESULT

FORMATIONS OR SUB-FORMATIONS RELEASED IN THE SET SAKOA

From the older to the most recent, the Sakoa series is made up of three formations:

3.1. Upper Carboniferous glacial tillitic formation.

The ***Upper Carboniferous glacial tillitic formation*** (Map 2) is exceptionally widespread the Karroo-Isalo graben. Its body has a lenticular shape, with thickness reaching up to 450 m in the grabens located in contact with the crystalline basement, in the Morondava basin, (left South of Madagascar). It is composed of black schistous clays alternated with layers of angular debris, blocks or the clods of earth, pebbles cemented by mud of glacial origin. No fauna has been reported in this sediment, resting in angular unconformity on the Precambrian crystalline basement. The Upper limit is marked by the abrupt change of the tillitic rock dated Upper Carboniferous- Lower Permian. The roof of this formation sinks from its outcrop up to 9 km, the East towards the South - West.



Map 2 : ***Upper Carboniferous glacial tillitic formation***

3.2. Upper Carboniferous-LowerPermian continental terrigenous formation.

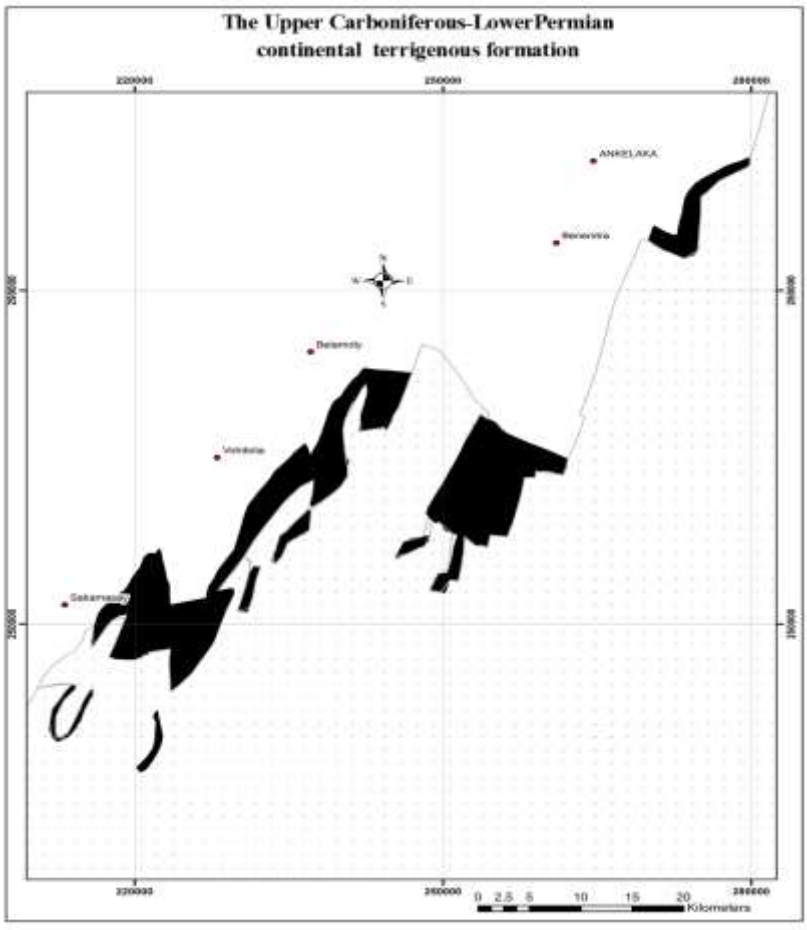
In this formation, two (02) Sub-formations were identified:

- **Upper *Carboniferous – Lower Permian limnic coal clay- sandy sub-formation***
- ***Lower Permian reddish clay-sandy continental sub- formation***

3.2.1- ***The Upper Carboniferous-Lower Permian continental terrigenous formation*** (Map 3) is distributed in mainly in the Karroo-Isalo graben and partially in the Karroo-Menabe graben of the Morondava basin. The materials brought by the paleorivers are deposited in a lake according to a fairly theoretical concentric zonation depending on the hydrodynamisme: pebbles along the banks, sands in the peripheral zones subjected to the action of the waves, muds in the deeper center of the graben and calmer. In fact the distribution of the materials depends on the position of the deltas in the lake. Its body has a lenticular shape, about 200-km long and 50 km wide.

The maximal thickness in the center of the graben can reach up to 150 m. The abrupt change of the coal-bearing terrigenous rock to the reddish clays dating materializes its upper limit. The arkosic sandstone intercalated with clays and coals with presence of the fossils of gangamopteria and glossopteria constitutes the main lithology of this sub- formation. The thicknesses of the coal intercalations of the coals vary from 1 to 5 m. The general textural characteristic of this sub - formation is of lacustrine origins. Sandstone grains are composed of quartz, feldspar, granit, zircon and mud. The characters of the sediments and the organic residues are strongly linked to the humid climatic conditions and to the relief of the Karroo graben in the Morondava basin. The eutrophic lakes, shallow, hot in summer, were rich in nutrientsand even in plankton, except for their high biologic productivity.

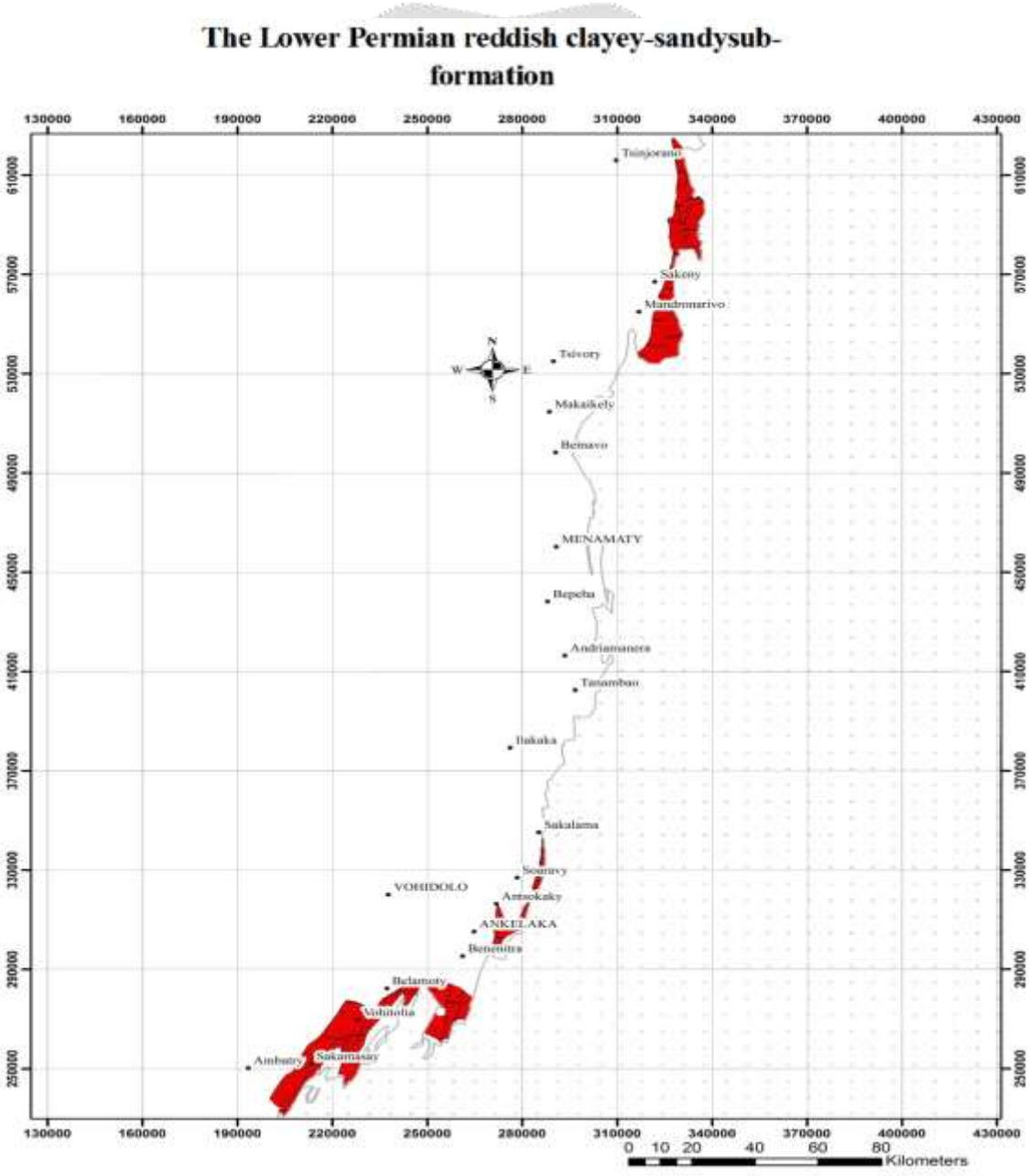
Due to the relatively weak hydrodynamic manifestations, stratifications or vertical schistosities rich in oxygen and under high temperature were noticed. On the other hand, the clayey intercalations are often, reducing environments.



Map 3: *Upper Carboniferous–Lower Permian limnic coal clay-sandy sub-formation*

3.2.2 ***The Lower Permian reddish clayey-sandysub-formation*** (Map 4) is widespread around Tsinjorano and Mandronarivo in the northen part of the Morondava basin and around Sakamasay, Belamoty and Ankelaka, East of Benenitra in part South of the Morondava basin, in particular in the grabens of the territory of the Karroo system. Its body has the shape of a gigantic lens, having like maximum thickness of 1400 m in the Karroo-Isalo graben. The roof of this sub-formation is materialized by the unconformity between the red clays and the Permian carbonate rock. It consists of arkosic sandstone with intercalations of red clays. In the upper part, it is composed of conglomerate, pebble and sometimes of the limestones debris. Remnants of primitive reptiles (theoropside, dicynodontid) and silicified wood have been found in the sediments of this sub-formation.

The latter formed mostly under a dry and arid climatic condition. But, the presence of deltaic, proluvial, lacustrine alluvial sediments marks intermittent rainy periods. In general, these reddish clayey – sandy sediments ofLower Permian dating are autochthonous.



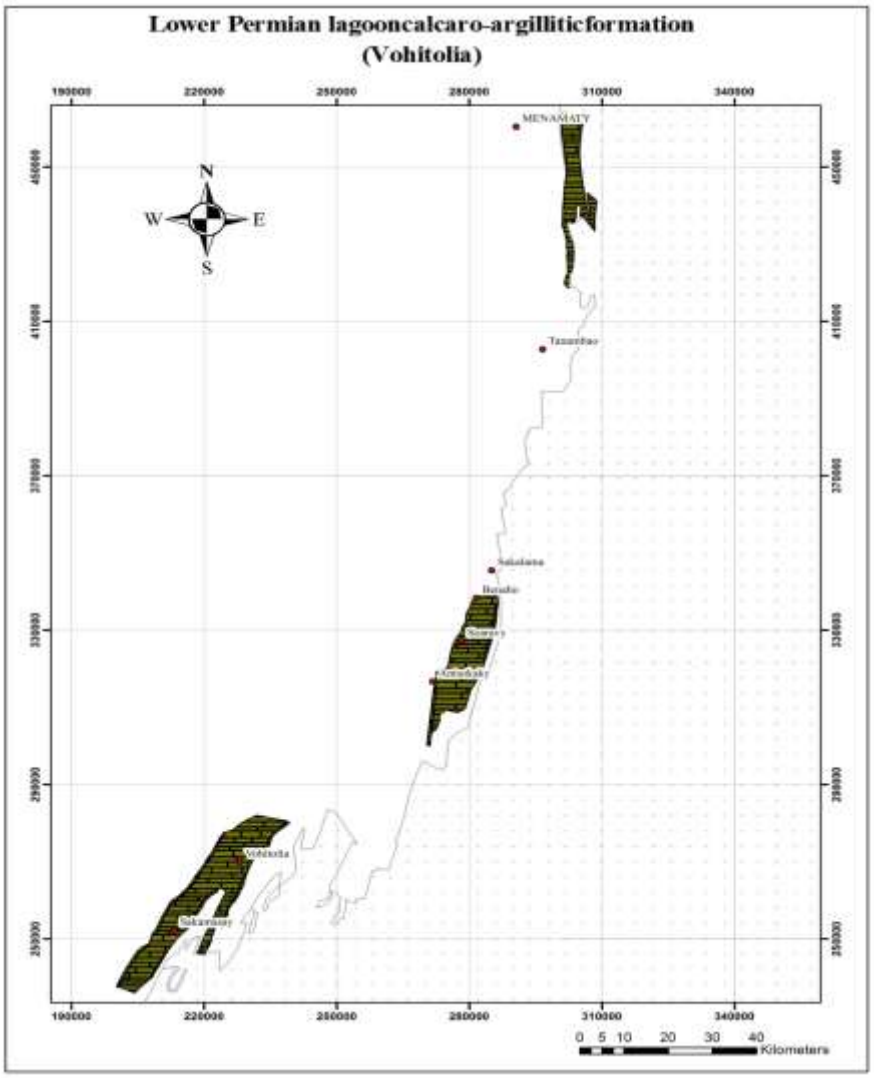
Map 4: *Lower Permian reddish clayey-sandy sub-formation*

3.3. Lower Permian lagoon calcaro-argillitic formation (Vohitolia).

It is arranged in the Morondava basin, Karroo-Isalo grabens and partially dispersed in the northern part or even around Menamaty, near the region of Tsimiroro, in the central part of the Morondava basin, in particular around Antsokaky, Soaravy and Benabo and in the southern part of the Karroo graben, around the Sakamasay and the Vohitolia (Map 5). Its geological body looks like a lens, relatively small in size. The maximum thickness of this formation reaches 40 m in the Karroo-Isalo grabens of the Morondava basin. The upper boundary of the formation is traced by the unconformity at the base of theUpper Permian conglomératic deposit. The lithological composition is predominated by argillites, with intercalations of limestones of laminar structure, even the stromatolites, geological concretions in concentric laminae, the oolitic, marking a shallow sea and few marine brachiopod fauna (Spirifer, Productus).The presence of organogenic constructions, among others, the biostromes or reef banks and the bioherm marks the specificity of this formation.

The organogenic calcareous sediments formed under shallow and warm marine conditions. Indeed, the existence of faunas in the sediments confirms the Lower Permian dating of this formation.

However, the boundary or the boundaries between the stratigraphic stages are chaotic. In the submerged part of the Karroo-Isalo graben, the minerals of this formation can undergo a deep reduction reaction; and the latter is interesting for favoring the conditions of the oil and gas formation and accumulation process.



Map 5*: Lower Permian lagoon calcaro-argillitic formation (Vohitolia)*

4. DISCUSSION

The Sakoa series consists of three (03) formations characterized in general by a transgressive cycle, from the glacial tillitic formation, when Madagascar was placed in the South polar zone, passing through the limnic clay terrigenous formation of great thickness of 1400 m, constituted by two (02) sub- formations and ends with the calcaro-argillitic lagoon marking the beginning of marine invasion in southern part of the Karroo– Isalo graben. The presence of the Lower Permian lagoonal calcaro-argillitic formation (Vohitolia) in the Karroo graben in the southern part of the Morondava basin generally justified, the epirogenic movement, marking the local land subsidence, which is generally a downward vertical movement occuring in the border region of the southern part of the Precambrian basement of Madagascar, due to the pressures undergone by the internal layers.

5. CONCLUSION

The analysis of the litho-stratigraphic, paleogeographic, structural formation and the release of the different formations and sub- formation allow us to discern the variations of the deposition regime of sedimentary series of the Sakoa series of the Karroo system in the Morondava basin.

It shows three (03) régimes constituting the formations and sub - formations:

- the first, essentially of glacial origin is defined by the tillitic formation corresponding to a period of intracontinental rifting. Most formations are synrifts and often end by very sharpunconformities. The variations of these formations are rapid and delimited by accidents of limited extension. This Permo-Carboniferous period ;
- the second, mainly of continental origin, is the terrigenous formation composed of two (02) sub-formations: ***Upper Carboniferous – Lower Permian*limnic coal-sandy clayey sub-*formation*** and autochthonous ***Lower Permianreddish clay-sandy formation***, formed duringintermittent rainy, deltaic periods, under a dry and arid climatic condition ;
- the third, mainly of mixed, predominantly marine origin, shows an important development of the formations composed of Vohitolia and Vohipanana limestones, which are practically found in the Karro-Isalo graben.

The specificity of the Sakoa series is the presence of fossil coal in the ***limnic clay-sandy sub- formation*** that accumulated in an epicontinental lake during a long rainy period.

After the analysis of the characteristics of the formations, in the composition of the sedimentary cover of the Malagay Karroo system, it was released: Three (03) formations with two (02) sub-formations, including:

- One formation of predominantly marine or lagonon origin wich is susceptible to bedrock (rich in organic matter, plankton), reservoir rocks or traps (oolitic coral, reefs and massives, fissured limestones)
- One ***reddish clayey-sandy sub- formation of continental origin***, which is susceptible of reservoir rocks.

6. REFERENCES

[1]. Geological annals of Madagascar – booklet n° XXXVI – summary of Malagasy geology by Henri BESAIRIE - Tananarive - National Printing office 1971

[2]. Study of the subsidence of the sedimentary basin of Morondava (Madagascar) within the setting of the framework of the geodynamic evolution of the East-African margin by Felix RAJAOMAZAVA – geological and geophysical center University of the sciences and techniques of the language doc 34095 - Montpellier cedex 5 - France - April 1992.

[3]. Record of sounding in Madagascar according to the documents of the Service of the Mines and synthetic log (1961) of the S.P.M.

[4]. Litho-facial analysis of the formations in the prospecting and exploration of the oil and gas diposits. Bakirov A. A. and Maltseva A. K. Moscow NEDRA 1985.

[5]. Theoretical bases and methods of research and prospecting for oil and gas deposits by BAKIROV A. A. and BAKIROV E. A. 1987

[6]. Structural characteristic of Madagascar sedimentary formation with its petroliferous province by Christoph Arvel RAVOLAHY. Moscou 1994