

CHARACTERISTICS OF THE MIDDLE JURASSIC (DOGGER) AND CRETACEOUS SEDIMENTARY FORMATIONS IN THE MORONDAVA AND MAJUNGA-DIEGO BASINS

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ABSTRACT

The Post-Karoo is a complex sedimentary series, composed of sandstones, marls, limestones with Dogger reefs. In the Majunga basin, this series appears in the form of a concentric aureole open towards the sea. In general, it is covered by vast recent volcanic flows, mainly marine with continental intercalations at the end of the Lower Cretaceous and in the Turonian lower.

Keyword: *Post-Karoo, dogger, concentric aureole, glauconious sandstone-marl, gypsiferous marls.*

1. INTRODUCTION

This article is part of the prospecting and investigation of oil and gas deposits in the Malagasy sedimentary basins. In this article, a low-cost and rarely used but efficient method is proposed for the regional investigation of oil and gas deposits in Madagascar. It makes it possible to identify formations or sub-formations vertically and structural zones horizontally, the shapes of geological bodies such as tabular layers, reefs, diapir folds, mouth bars, lithological bevels with their respective lithological compositions. , to identify their paleogeographic conditions during the accumulation of post-karoo deposits, their dating of formations, the presence of organic, microbiological and biochemical substances and to identify the possibility of petroleum systems or even possible natural reservoirs with tectonic and stratigraphic barriers and lithological elements likely to trap oil and gas. These post-karoo sedimentary deposits are mainly formed during the transgressive episode caused by the epirogenic movement relating to the lowering of a significant western coastal part of Madagascar.

2. MATERIAL AND METHODS

2. 1. Materials

The lithological section obtained gotten from the drilling are used to be correlated when determining the shape of the body of the formations or sub - formations and of the establishing of the natural reservoirs or the petroleum system. The formations in the Karoo system which date from Upper Carboniferous to the Lower Jurassic were identified from data from 55 boreholes drilled by SPM, CHEVRON, CONACO, COPETMA, MOBIL, AGIP, OCCIDENTAL, AMOCO, OMNIS and other companies, located in the three large Malagasy sedimentary basins. The term Karoo encompasses sedimentary and intrusive formations, deposited or emplaced in Africa, in intra and peri- continental basins located South of the Equator [2].

They are: the Karoo basin (South Africa), the Etjo basin (Botswana), the Limpopo and Zambèze basins (Zimbabwe, Mozambique), the Congo basin (Zaire), the Rovuma valley (Tanzania), the Mombasa basin (Kenya), the Morondava and Majunga-Diego basins (Madagascar) [3].

2. 2. Methods.

The method consists in releasing a geological body called "Formation or sub - formation" which is different from the understanding of the "facies".

Characteristic of the formations and sub - formations.

The « facies » is generally closely linked with paleogeomorphology as for the « formation », in addition to these two (02) aforesaid geological conditions, it is mainly linked with the tectonic movement and was formed in regional geological structure, during a well –defined period.

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

In this article, a formation is a concrete geological body, delimited by the homogeneity of its lithological composition formed under well-defined paleotectonic and paleogeographic conditions, corresponding to stratigraphic stages or series, rarely to a few series or part of stage [4] [5]...

The analysis of the characteristics of Mesozoic, Cenozoic sedimentary formations of the western coast of Madagascar makes it possible to clarify, each formation released in the structural areas corresponding, the following clauses:

- 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 composition and grouping in profile,
- Restoration of the paléotectonic, facial - paléogéographic, géochimical conditions of formations and their evolution.
- Description of contact area characters [4].

3. RESULT

FORMATIONS OR SUB-FORMATIONS RELEASED IN THE POST-KARROO.

1. Marine sandstone-clay-limestone formation from the Middle Jurassic (Dogger)

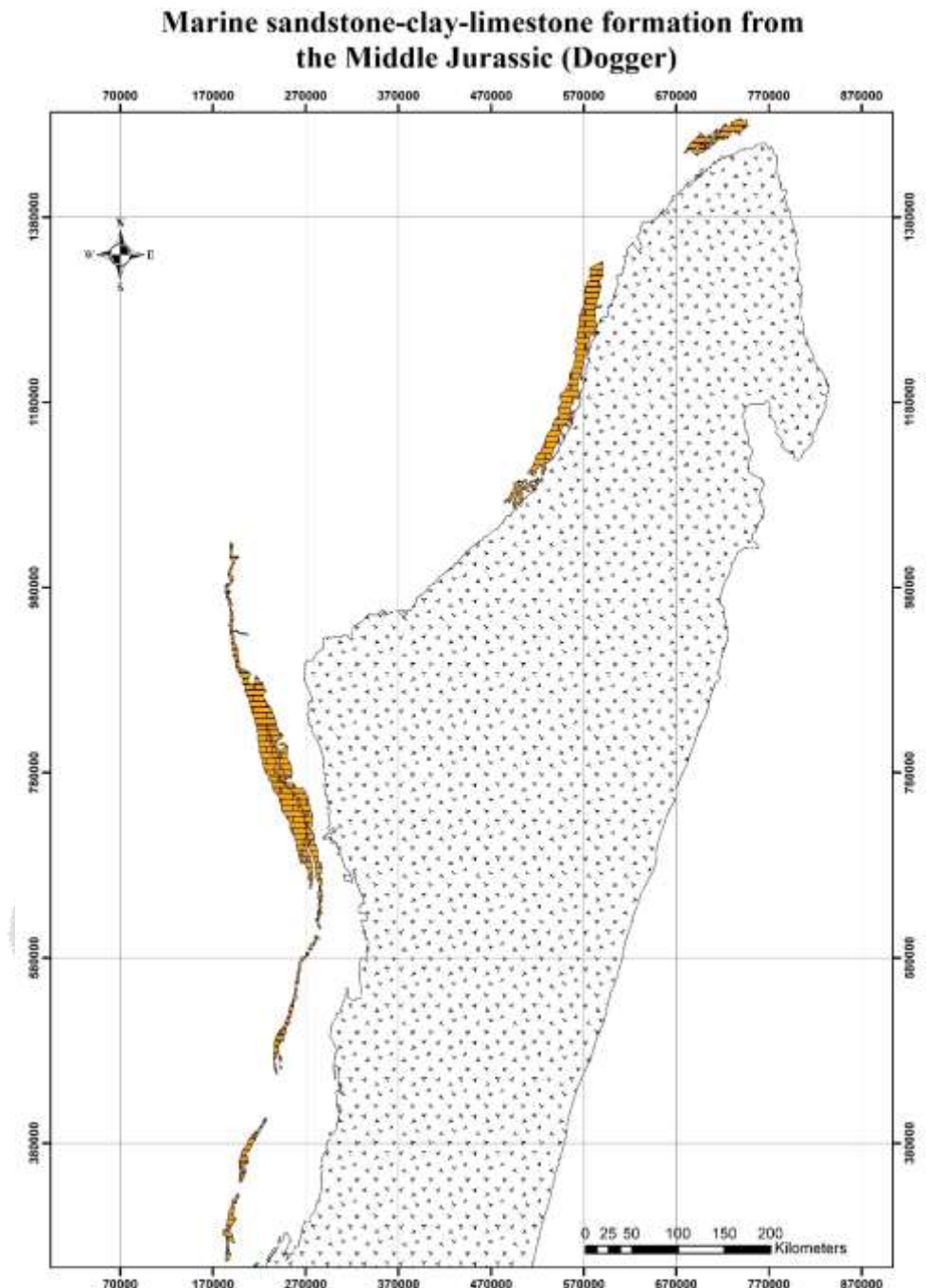
The geological body of this formation has a lenticular shape with a thickness varying from a hundred meters to 6000 meters.

This formation dating from Aalenian – Bajocian – Bathonian, is made up of an alternation of sandstone with cross-stratification and red clays of lagoon origin with faunas of species of the genus *Lumachelles* in Corbula, *Lamellibranche*, gigantic reptiles from the group of dinosaurs belonging to the genus *Bothriospondylus* (15 to 20 meters long) which left remains in the regions of Antsohihy and Port-Bergé, Pont Kamoro; and then its upper part is composed of abundant intercalations of marine limestone rich in *Rhynchonella*, due to general marine invasion.

This formation is widespread in the Morondava basin, which is the case of the marine limestones of Bemaraha, of the horst of Manera where its thickness can reach up to 2000 meters, containing sea urchin faunas. South of the Tsiribihina, its lithological composition is characterized by mixed facies limestones. It passes through limestones with *Polypiers* forming a coral barrier surrounded by para-reef sediments with *Lamellibranches* and *Urchins*, fossilized atolls (annular reefs) between Mangoky and the South of Onilahy and around South of Sakaraha.

It is also found in the western parts of the Majunga and Diego basins, notably in the Ankara-Kelifely grabens, the Ambilobe subsidence region, the Ampasindava-Sambirano monocline where its thickness varies from 3000 to 6000 meters.

The limestones of the upper part of the Middle Jurassic present a karst morphology with sinkholes, stones and cut by deep canyons.

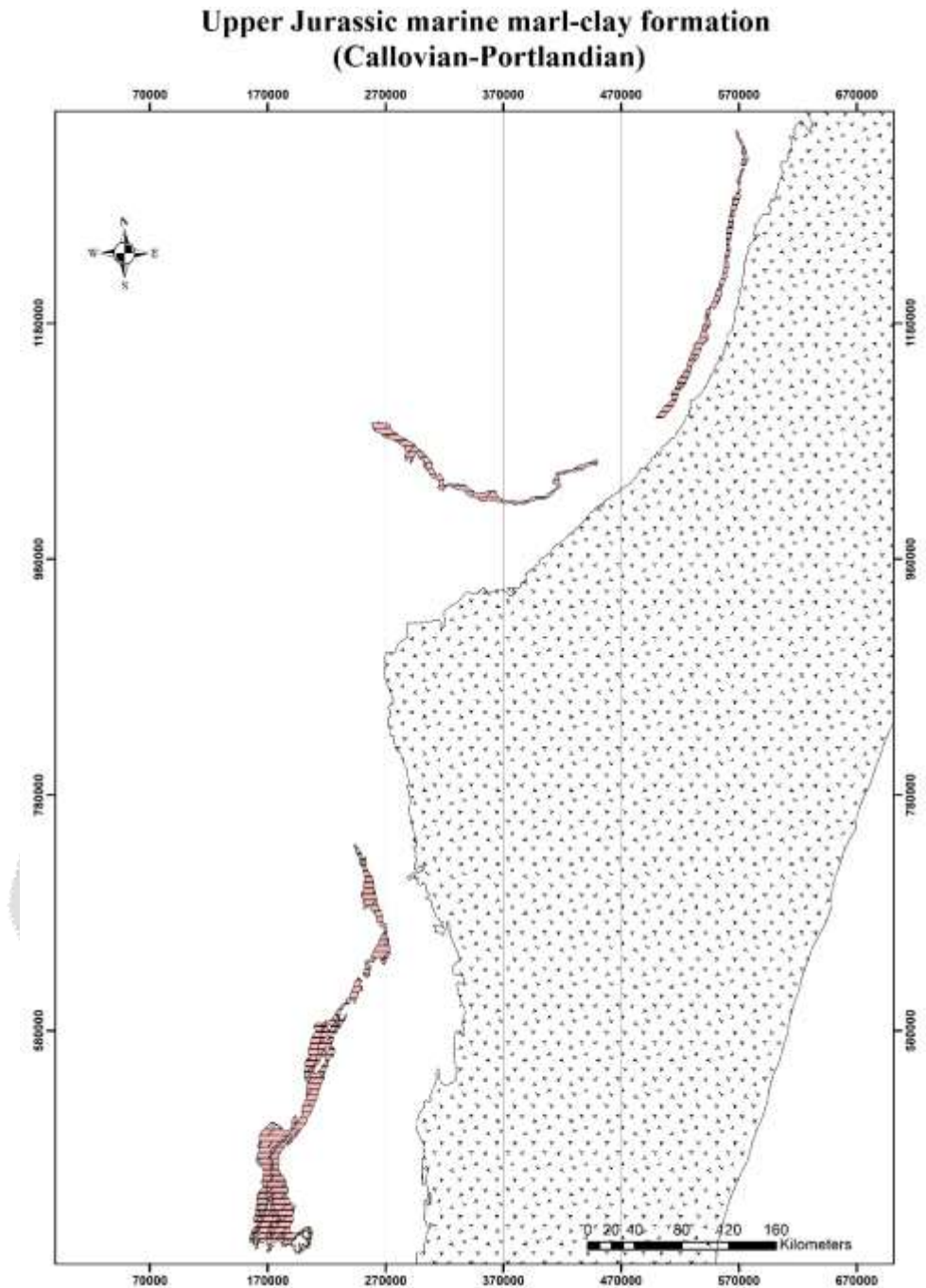


MAP 1 : Marine sandstone-clay-limestone formation from the Middle Jurassic (Dogger)

2. Upper Jurassic marine marl-clay formation (Callovian-Portlandian)

This formation is composed of much more clayey and marly facies with *Macrocephalite* and *Reineckeia* in the Andranomantsy tectonic gap which cuts into the Analamera plateau south of the Irodo and ends in gaps. In the Majunga basin, it is depressed, matching the existing general concavity. To the north of the Ankara plateau, it collapsed at the foot of the great fault and covered by basalt flows. From Maromandia to the south of Soalala, it is represented by a wide marly band containing a succession of *Macrocephalite*, Sea Urchin and small, often pyritic *Ammonite* faunas (*Reineckeia*). It constitutes the bedrock of the alluvial plains of the Doroa to the west of Antsohihy, of the Sofia and of the Bemarivo in the region of Port Bergé, of the Betamotamo tributary to the north of Mahajamba, the Kamoro area up to Ambato-Boeni, then the plain of Iabohazo, Andarnomavo and Kapiloza.

The Oxfordian marls with *Mayaites* crop out in places at Bobasakoa and as well as near Ampombiantombo, the Argovian marls with the Tithonic *Bélemnites*. Its geological body has a lenticular shape and is more than 1300 meters thick in the Ambilobe subsidence zone. It is a formation of marine origin containing organic matter, notably plankton. It is likely to be bedrock.



MAP 2 : Upper Jurassic marine marl-clay formation (Callovian-Portlandian)

3. Mixed sandstone-marl formation of the Cretaceous

3.3.1. Marine glauconious sandstone-marl subformation of the Neocomian (Berriasian-Valanginian)

This sub-formation is arranged in the Majunga basin except to the west of Betsiboka, more particularly in the region of Sitampiky and Antsohihy. It is also found west of Ihopy. It is also present in the north of the Morondava basin, in particular in the Maintirano region and made up of glauconious limestones in Spiticeras, marl in Duvalia. Between Mangoky and Onilahy, this sub-formation passed into glauconious marls with Bélemnites.

It has a lenticular geological body characterized by great thickness towards the coast.

It is composed of marls and transgressive greenish glauconious sandstones, forming during marine volcanism.

33.2. Mixed marl-sandstone subformation with continental predominance of the Valanginian-Hauterivian – Barremian-Aptian-Albian.

This subformation is widespread in the Sitampiky and Antsohihy region, particularly in Ankerika where it is made up of lower Valanginian marls with Bélemnites, Duvalia and Ammonites (Berriasella), upper Valanginian sandstones with Holcostephanus, clayey sandstones and clays. with ferruginous nodules and platelets and continental sandstones with cross-stratification from the Hauterivian-Barremian, in the middle of which are some Hauterivian marine intercalations with Saynella and Menuthiocrioceras. It continues to Betsiboka.

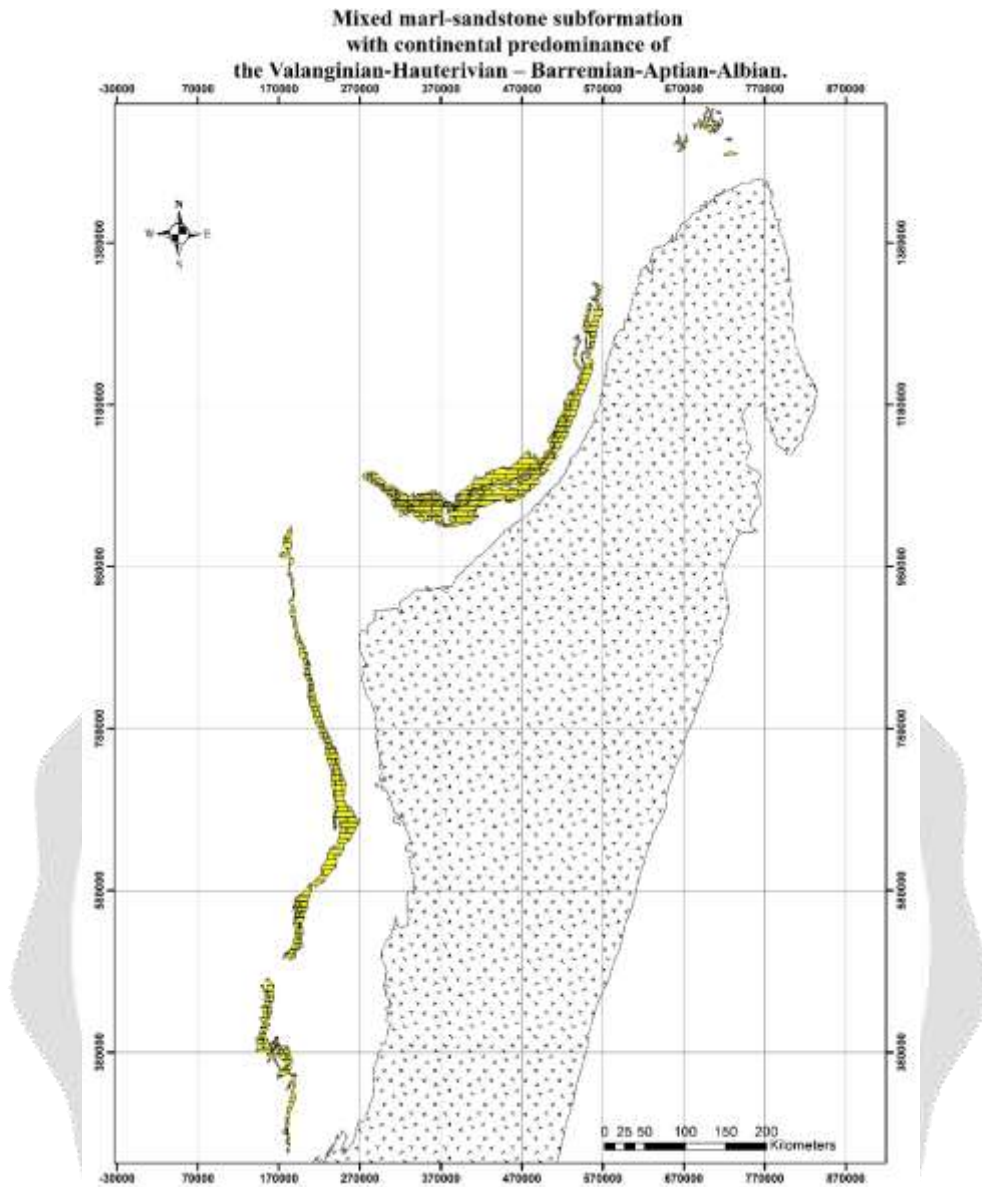
In the north of the Morondava sedimentary basin, the Maintirano region, it is made up of Duvalia marls from the Valanginian-Hauterivian, Crioceras limestones from the Barremian, white marls from the Aptian and red sandstones with thin marine intercalations of the Albian.

Between Mangoky and Onilahy, the subformation is composed of marls with microfaunas, transgressive glauconious sandstones with Bélemnites, Saynelle, Menuthiocrioceras from the Hauterivien and red clayey sandstones from Clansaysian (Upper Aptian), Acanthopliite, Pervinquieria, Douvilleiceras (Upper Albian) , Australiceras limestones from the Aptian and marls from Douvilleiceras and Pervinquieria.

Its geological body is lenticular in shape with a thickness of several thousand meters. In Ankararano, the thickness of the sandstones is great and reaches its maximum. Mixed marl-sandstone sedimentary deposits with some marine intercalations with predominantly continental Aptian Acanthopliites cover the entire Majunga basin. West of Mahavavy, more particularly in Befamonto, Sororaina and north of Sitampiky, we find faunas from the Lower Aptian with Deshayites, from the Gargasian with Aconoceras and Nolaniceras, from the Clansaysian with Acanthopliites. This facies group is represented in the Radama peninsula and south of Analalava.

The particularity of this sub-formation is the presence of gypsiferous marls with Oxytropidoceras, Manuaniceras from the Middle Albian with a rich fauna of small pyritic Ammonites (Hysteroceas), then calcareous Ammonites with Pervinquieria, Douvilleiceras (Upper Albian) and more clays or less glauconious.





3.3.3. M **MAP 3:** *Mixed marl-sandstone subformation with continental predominance of the Valanginian-Hauterivian – Barremian-Aptian-Albian.* **flows from the Cenoma**

In the Morondava basin, around Onilany, this sub-formation transgressively covers the earlier sub-formation, where its lithological composition is:

- marls with small pyritic Ammonites (Mantelliceras, Scaphites) and clayey sandstones with Mantelliceras and Acanthoceras from the Cenomanian;
- yellow sandstones in Fagesia, Protocardium hillanum from the Turonian
- greenish sandstone in Barroisiceras from the Coniacian
- Santonian interlocking continental sandstones
- medium basalt flow
- limestone sandstones and marls with Alectryonia Pachydiscus from the Maestrichtian.

It is also present in the Maintirano region where it is made up of:

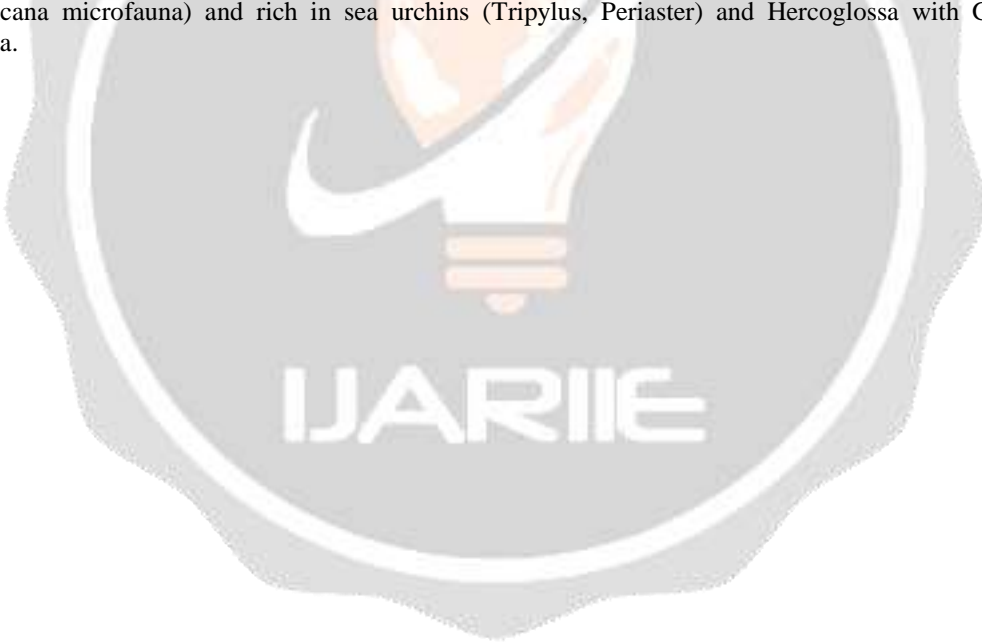
- continental red sandstones predominant in the North with marine intercalations of Cenomanian
- south of Antsalova, sandstones and marls with Ammonites from the Cenomanian
- Turonian limestone sandstones in Fagesia and Vasoceras
- lower basalt flows
- gray marls and limestone banks in Peroniceras and Barroisiceras from the Coniacian
- yellow marls and marly limestones with Prionocycloceras from the Coniacian
- alternation of marls with septarias, marly limestones with fossiliferous concretions and

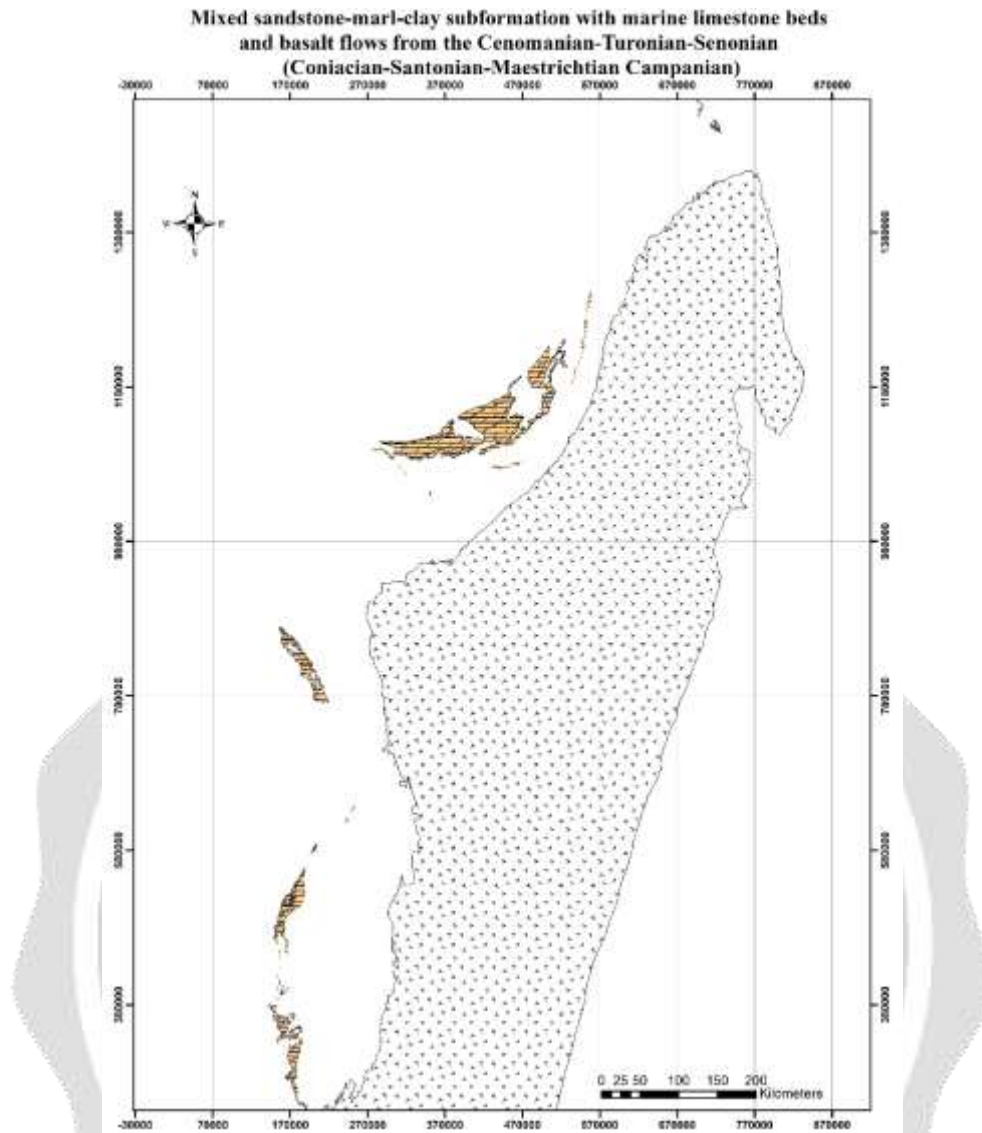
- limestone sandstones with Texanites from the Santonian
- sandstone-marl-limestone with chalky limestones with great abundance of Ammonites from Campanian (marine in the North and continental in the South)
- marl-limestones with Lamellibranches of marine origin from the Maestrichtian

Between Mangoky and Onilahy, this sub-formation is made up of:

- Cenomanian marl and Acanthoceras sandstone
- Sandstone with Vascoceras from the Turonian
- Lower basalts
- Crossed continental sandstones from the Coniacian
- Santonian-Lower Campanian marine sandstones.

North of the Majunga basin up to Sofia, the Cenomanian is formed of clays with nodules and limestone beds and at the top, coarse sandstones with faunas of Acanthoceras, Mantelliceras, Stoliczkaia. South of Sofia, it passes into crisscrossed sandstones of continental origin (Ankarafantsika sandstone), while to the west of Ihopy, its base becomes marine again. The Turonian is marked by basaltic flows and in the north of the basin, by sandstone, marl-clayey with limestone banks poor in Ammonites, rich in sea urchin *Protocardium hillanum*. In the Marovoay region, the Turonian facies is made up of sandstone clay of lagoonal and mixed origin with bones of Dinosaurs and rare Lamellibranches, becoming continental in the West with crisscrossed sandstones and clays with calcareous concretions. To the north of the basin, in the Antonibe area, marine intercalations from the Coniacian to Barroisiceras, from the Santonian to *Pseudoschloenbachia*, from the Campanian to Lamellibranches were observed; while the rest of the basin, with the exception of the Maestrichtian, is continental, presents a succession of clayey, sandy, yellowish sandstones, alternating with gray or brown clays, generally sandy containing remains of Dinosaurs (*Megalosaurus*) and Wood silicified. The Maestrichtian marl-limestone facies is of marine origin everywhere with oyster marls (*Pycnodonta*, *Alectryonia*, *Crania* and *Globotruncana* microfauna) and rich in sea urchins (*Tripylus*, *Periaster*) and *Hercoglossa* with *Glogiberine* microfauna.





MAP 4: *Mixed sandstone-marl-clay subformation with marine limestone beds and basalt flows from the Cenomanian-Turonian-Senonian (Coniacian-Santonian-Maestrichtian Campanian)*

4. DISCUSSION

INSTALLATION OF CONTINENTAL, MARINE AND LAGOON AREAS.

1. MARINE AND LAGOON EPISODE

- FROM THE MIDDLE AND UPPER JURASSIC

A widespread invasion of a much clearer sea has been proven in the Majunga-Diego basin. The deposits are generally composed of particularly large limestone.

During the Middle Jurassic, the marine gulf does not yet seem to have gone beyond the south of the Morondava basin. The Upper Jurassic shows clear and deep marine formations made up of marly, clayey and schistose rocks which are as follows:

- o Marine sandstone-clay-limestone formation from the Middle Jurassic (Dogger)
- o Upper Jurassic marine marl-clay formation (Callovian-Portlandian)

FROM LATE CRETACEOUS TO MIDDLE EOCENE

Transgressive sedimentary formations were observed from the end of the Aptian to the middle Eocene, having very uniform series, with a predominance of clay facies at the beginning of the formation, ending with the Cheringoma limestones of very great extent. .

- o Mixed sandstone-marl formation from the Cretaceous
- o Marine glauconious sandstone-marly subformation of the Neocomian (Berriasian-Valanginian)

2. CONTINENTAL EPISODE

During the regression cycle from the Upper Cretaceous to the Middle Eocene, the depositional regime is predominantly continental:

- o Mixed marl-sandstone subformation with continental predominance of the Valanginian-Hauterivian – Barremian-Aptian-Albian.

5. CONCLUSION

The litho-stratigraphic, paleogeographic and structural analysis of the post-karoo formations and the identification of their different formations and sub-formations allow us to discern the variations in the deposition regime of the sedimentary series of the Morondava and Majunga-Diego basins. They show a regime of distinct deposits constituting the formations and sub-formations which are mainly marine, with a significant development of post-rift formations composed of limestones, marls and shales, which are found practically in all the coastal basins of Madagascar.

Despite the very early invasion (in the Toarcian) of an epicontinental sea in certain basins (Mahajanga, Morondava) this type of formation regime only began at the beginning of the Middle Jurassic, that is to say, in the Bajocian. A generalized unconformity (or post-rift unconformity) materializes the base of these formations and marks the beginning of the oceanic opening

After the analysis of the characteristics of the post-karoo formations, in the composition of the Malagasy sedimentary cover, it was identified: Three (03) formations of cover rocks (thick layers of clay) and reservoir rocks or traps (reefs and oolitic coral massifs, fissured limestones) and (03) sub-formations mixed, of marine or lagoon origin which are susceptible to source rocks (rich in organic matter, planktons).

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