WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Biostratigraphy and Paleoenvironment of the Aptian-Campanian of Morafeno, Ambilobe basin, Madagascar

[a]RASOLOFOTIANA Edmond, [b]NIVOHARISANDRATRA B. V., [c]RANAIVOSOA V.,

[a,b,c]Mention Bassins sédimentaires Evolution Conservation, Domaine Sciences et Technologies, Université d'Antananarivo BP 906, 101 Antananarivo, Madagascar, *edmondras@yahoo.com*, rnvoaj@gmail.com

ABSTRACT

Biostratigraphy and paleoenvironment in the Morafeno site, Ambilobe basin are determined from the micropalaeontological study. Physico-chemical treatments, calcimetric and geochemical analyses of the collected sediments showed a microfaunal association, constituted by Foraminifera (61 benthic species, 20 planktonic species) and Ostracods (10 species).Planktonic Foraminifera are abundant, represented by *Hedbergella, Globotruncana, Whiteinella* and *Rotalipora, Archaeoglobigerina*. They allowed the stratigraphic delimitation in the Morafeno formation from the Aptian to the Campanian. The geochemical constituents in the sediments as well as the microfauna indicate a marine environment of the internal platform, shallow (from 0 to 200 m) belonging to the infralittoral stage; a warm and arid climate prevailed. The Cretaceous marks an existence of two faunal provinces between Madagascar and India, then between Madagascar, Africa and Europe.

Keywords : Calcimetry – Geochemistry- Foraminifera - Ostracodes – Cretaceous - Morafeno

1.Introduction

The Cretaceous is an important period in the biological diversification in which many geological phenomena occurred. The sedimentary series related to this period is largely represented in the North of Madagascar. However, the sedimentary basin of northern Madagascar is geologically known, but rarely been the subject of biostratigraphic and paleoecological studies. Microfossils remain important temporal and biostratigraphic markers in sedimentary formation. This work aims to determine the stratigraphic limits of Cretaceous sedimentary formation in Morafeno site by the study of the faunal associations encountered. The principle is to inventory the microfossils (Foraminifera, Ostracods,...), to study the faunal associations and to carry out a geochemical analysis for the sediments in order to provide a precisions on the paleoenvironment reconstitution and the paleobiogeography .

2.Geological setting

The Ambilobe sedimentary basin occupies the extreme northwest of Madagascar. It is limited to the West by the Ampasindava peninsula which separates it from Mahajanga basin, and to the East, by the Indian Ocean. (Besairie, 1971). The site studied is relative to the middle and upper Cretaceous. Sedimentary series is marked by clay-limestone base carrying volcanic rock flows and some limestone field. These layers are accompanied by iron mineral (pyrite) and gypsum.

3.Materials and Methods

The materials used respond to the different stages of sample processing in the laboratory: beaker, series of sieves, petrie box, oven, binocular magnifier and Bernard's Calcimeter,... The samples were taken on sediments in place unaltered after stripping the superficial parts. The collected sediments are treated in the laboratory for physico-chemical treatment, calcimetry and geochemical analysis.

The studied samples come from Morafeno site which is located at 4 Km from Antsiranana city, in the Ramena road, Commune and District Antsiranana I, Region of Diana. The geographical coordinates are: 12°18'25.5"Latitude South; 49°18'09.0"Longitude East; Altitude: 0.5m. (Figure 1)

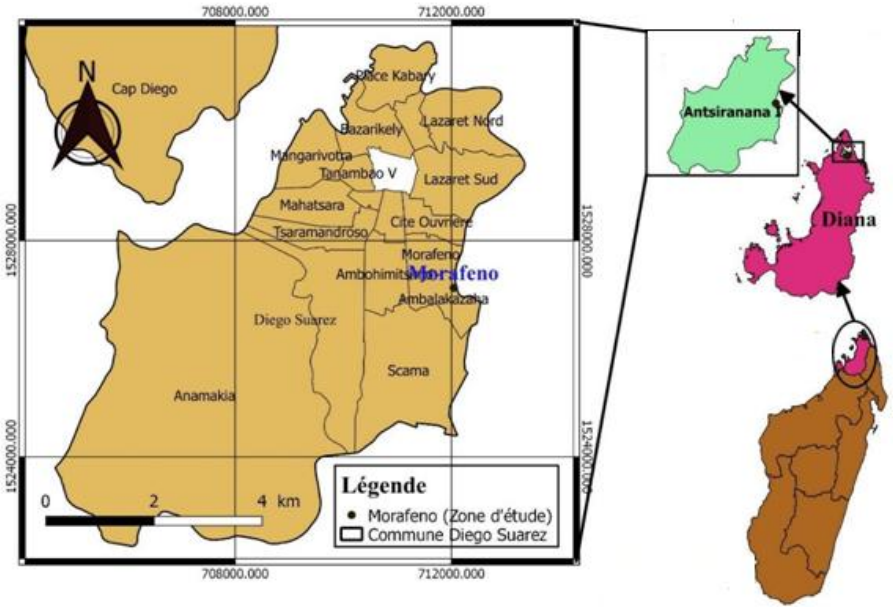


Figure 1: Location of the study site (source: BD 500)

4. Results

4.1. Calcimetry

The calcimetry analysis for the samples in Morafeno site is summarized in the following table.

Table 1: Calcimetric analysis

Samples	Average volume of CO2 released (ml)	CaCO3 (%)
MF5	41.07	34.23
MF4	35.49	29.58
MF3	81.14	67.62
MF2	38.46	32.05
MF1	29.17	24.31

The $CaCO_3$ content in the sample of layers MF1, 2, 4, 5 has an average value 30%; while the sample MF3 particularly reached 67,62%. There was a progressive improvement of the conditions favorable to the carbonate precipitation (temperature, luminosity, pH, eustatic level), then these conditions tend to regress gradually.

4.2 Geochemical analysis

The major elements proportion (SiO2, CaO, MgO, Fe2O3, Al2O3), in the samples of Morafeno formation is represented in table 2.

Table 2: Geochemical analysis

Samples	% SiO2	%CaO	%MgO	%Fe2O3	%Al2O3
MF5	43.21	24.96	0.44	0.97	2.86
MF4	49.44	22.56	0.54	1.08	1.33
MF3	43.71	40.93	1.20	1.13	2.38
MF2	56.91	20.26	0.44	1.40	1.24
MF1	51.45	19.08	1.09	2.16	3.17

SiO_2 and CaO contents are very high in the Morafeno site, but other elements are generally very weak (Al_2O_3, Fe_2O_3, MgO); SiO_2 rate in the sediments is high with an average value 48%. The CaO is increasing progressively in the two basal layers to reach an optimum value 40.91%, and then it regresses to a value 20% for layers MF4 and MF5. This indicates the sea depth variation and the site temperature. The MgO content is weak (1%), indeed it is considered as a trace element, marking a warm environment.

4.3 Lithology

Rocks classification depends on the proportion of chemical elements. The ternary diagram takes into account the rate of SiO_2, $CaCO_3$, and $Al2O_3$ to demonstrate the rocks nature either sandy, or clayey, or limestone.

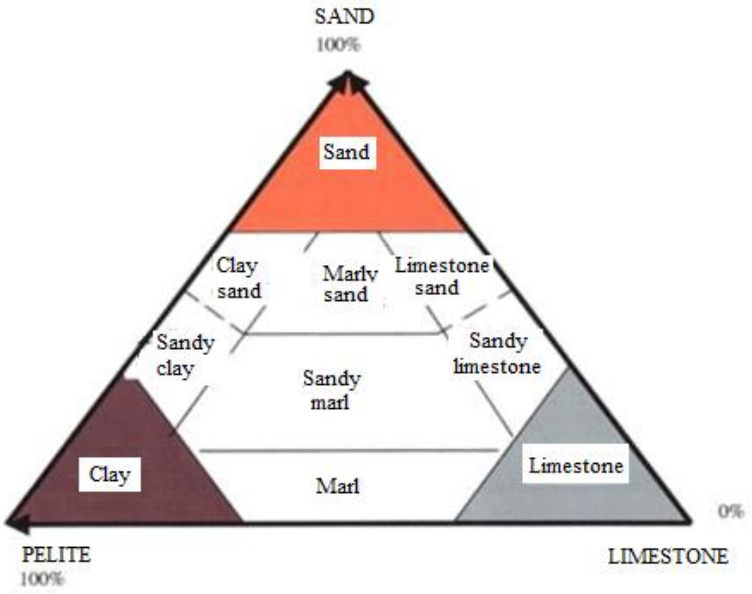


Figure 2: Ternary diagram (sand, limestone and clay) (Source: http:/www.u-picardie.fr/beaucham/cours -sed/sed-2.htm)

Geochemistry results bring a precision on the nature for the rocks. In this case, SiO_2 content corresponds to these values: between 43% and 56%; $CaCO_3$ has an average value of 37%: the sediments are therefore sandy-carbonated; Al_2O_3 content corresponding to clay is generally weak 2%, the sediments are weakly clayey. Consequently, the classification of these sedimentary rocks is shown in the following table 3.

Table 3: Combination of calcimetry and geochemistry results

Samples	**CaCO3** (en %)	**SiO2** (en %)	**Al2O3** (en %)	**Rocks**
MF05	34.23	43.21	2.86	Limestone sand
MF04	29.58	49.44	1.33	Limestone sand
MF03	67.62	43.71	2.38	Sandy limestone
MF02	32.05	56.91	1.24	Limestone sand
MF01	24.31	51.45	3.17	Limestone sand

Lithology of Morafeno Formation is generally composed by the loose sediments (Figure 3).

Age	Samples	Thickness (m)	Log	Lithology
APTIAN-CAMPANIAN	MF5	4.8		Tender limestone sand, fine-grained, yelow-orange
	MF4	4.5		Tender limestone sand, fine-grained, yelow, with gypsum crystals
	MF3	3		Tender sandy limestone, whitish also known as sandy chalk
	MF2	2		Tender limestone sand, fine-grained, light brown with gypsum crystals
	MF1	1		Tender limestone sand, fine-grained, light yelow

Figure 3: Lithological section of Morafeno (Production: Strater)

4.4 Faunal composition

The sediments collected in the Morafeno site have delivered a microfaunal association, made up of Foraminifera (benthic and planktonic) and Ostracoda.

The environment is very rich in microfossils, 61 species grouped in 24 genera of benthic Foraminifera belonging to the family of: Ammodiscidae, Bolivinidae, Ellipsoidinidae, Pleurostomellidae, Rheophacidae, Stilostomelloidae, Vaginulinidae, Lagenidae, Nodosariidae, Frondicullariidae, Planorbulinoidae, Miliolidae, Spiroloculinidae, Nonionnidae, Gavelinellidae. 20 species gathered in 14 planktonic genera, grouped in the family: Globotruncanidae, Heterohelicidae, Gumbelina, Hedbergellinidae, Globigerinidae, Polumorphinidae, Rotaliporidae. The Ostracods are entirely constituted by 10 marine species distributed over 8 genera. These recognized genera belong to the family Cytherellidae, Cytheridae, Cytherideidae, Trachyleberidae, Brachycytherinae, Bythocyprididae, Pontocyprididae. Foraminifera and Ostracods are present and abundant in all layers of Morafeno Formation (MF). In particular, MF3 level represents a richness in faunal diversity compared to the other levels.

1.Ammodiscus cretaceus, 2. *Ammodiscus semiconstristus,* 3. *Bolivina pseudoplicata,* 4. *Bolivina pseudopunctata,* 5.*Cristellaria helicina,* 6.*Cristellaria crepidula,* 7.*Cristellaria calcar,* 8. *Nodosarella tuberosa,* 9. *Pleurostomella, acuminata,* 10. *Leptohalysis catella,* 11. *Strictocostella,* 12.*Tribrachia,* 13.*Lenticulina sternalis,* 14. *Lenticulina insulsus,* 15. *Lenticulina gaultina,* 16.*Lenticulina thalmanni* 17.*Lenticulina ouachensis,* 18. *Lenticulina gibba,* 19. *Lenticulina* sp, 20. *Astacolus cretaceous,* 21.*Astacolus gryi,* 22. *Astacolus albatrossi,* 23. *Astacolus crepidulus,* 24. *Amphicoryna scalaris,* 25. *Marginulina cubana,* 26.*Marginulina seminotata,* 27.*Marginulina advena,* 28.*Saracenaria* sp.,29. *Saracenaria schencki,* 30. *Vaginulina* sp1,31.*Vaginulina strigillata,* 32. *Lagena semiinterrupta,* 33. *Lagena elongata,* 34. *Lagena lyeli,* 35. *Lagena* sp1,36. *Nodosaria* sp1,37. *Nodosaria* sp2,38. *Nodosaria vertebralis,* 39. *Dentalina communis,* 40. *Dentalina mutabilis,* 41. *Dentalina bradyensis* 42. *Dentalina* sp1, 43. *Dentalina filiformis,* 44. *Frondicularia eulimbata,* 45. *Frondicularia archiaciana,* 46. *Frondicularia turgida,* 47. *Frondicularia major,* 48. *Frondicularia compta villosa,* 49. *Frondicularia inversa,* 50. *Tristix excavata,* 51. *Cibicides lobatulus,* 52. *Cibicides stephensoni,* 53. *Cibicides* sp,54. *Cibicidoides compressus,* 55. *Cibicidoides pachyderma,* 56. *Triloculina*,57. *Spiroloculina planulata,* 58. *Florilus scaphum,* 59. *Pullenia cretacea,* 60. *Gyroidinoides globosa,* 61.*Gyroidinoides nitidus*,62.*Globotruncana appenninica,* 63.*Globotruncana globigerinoides,* 64.*Marginotruncana cfp coronata,*
65.*Whiteinella archaeocretacea,* 66. *Heterohelix globulosa,* 67. *Heterohelix* sp.,68. *Rectogümbelina longa,*
69. *Rectogümbelina* sp.,70. *Hedbergella* sp.,71. *Hedbergella madagascariensis,* 72. *Orbulina,* 73. *Archaeoglobigerina,* 74. *Guttulina,* 75. *Pyrulinoides acuminata,* 76. *Pyrulinoides* sp., 77. *Ramulina tappanae,* 78 .*Rotalipora brotzeni,* 79. *Rotalipora appennica,* 80. *Rotalipora cushmani* , 81. *Praeoglobotruncana stephani,* 82. *Cytherella circumrugosa,* 83. *Cytherella ex gr. Ovata,* 84. *Cytherelloidea ghotaruensis,* 85. *Cytherelloidea oertlii,* 86. *Majungaella cf. pyriformis,* 87. *Pirileberis makatiniensis,* 87. *Pirileberis makatiniensis*,88. *Taracythere antakaranaensis*,89. *Malagasyella* Aff. Rajendrai,90. *Robsoniella postelongata*,91. *Pontocyprella* sp.

4.5. Distribution of the groups of microfossils encountered

Planktonic forms represent 90.24% of the microorganisms in this site; the most abundant are the genera *Hedbergella, Globotruncana, Whiteinella, Praeoglobotruncana* belonging to the family Hedbergellinidae, Rotaliporidae, Globigerinidae. However, the benthic forms are abundant in numbers of genus but constitute only 8.72% dominated by the Vaginulidae (Lenticulina), Cibicididae (Cibicides and Cibicidoides) and the morphogroups with elongated tests (*Dentalina* with which Marginulina, *Nodosaria* are mainly associated). Ostracods are less abundant than Foraminifera, that is to say 1.04% of these microfossils, the most numerous being the genus *Cytherella* grouped in the family Cytherellidae and the genus Taracythere of the family Trachyleberidae. The predominance of planktonic foraminifera indicates a marine environment with a fairly high bathymetry. The spatio-temporal microfossils distribution depends on the variation sea level.

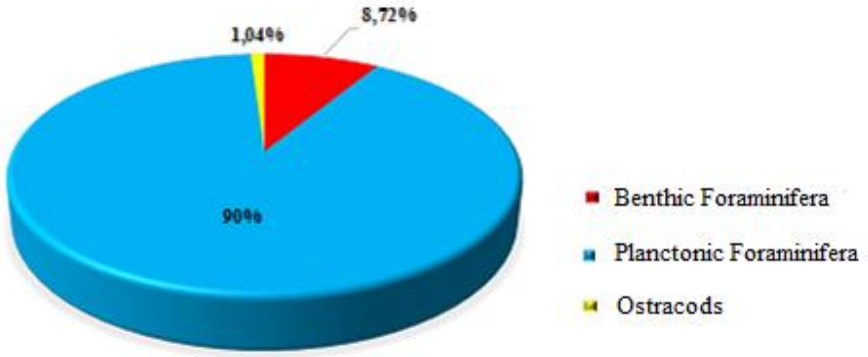


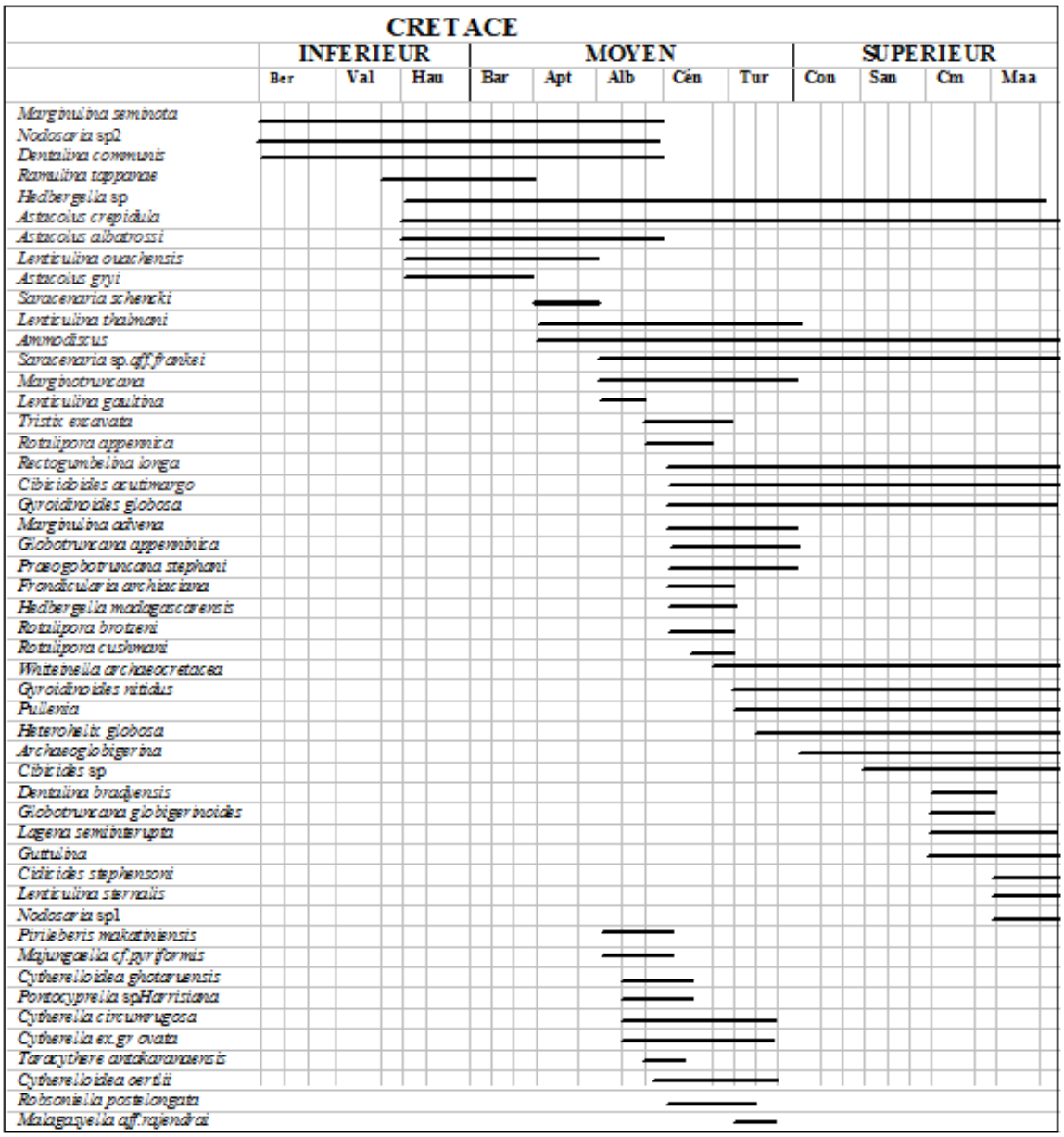
Figure 4 : Distribution of microfossils

5. Discussion

5. 1. Biostratigraphy

Biostratigraphy is the characterization of geological layers by their biological content, an excellent stratigraphic marker. Thus, species distribution in the Morafeno formation is illustrated inside the following table 4:

Table 4: Stratigraphic distribution of Foraminifera and Ostracods



The distribution of Foraminifera and Ostracods from Morafeno site define the Cretaceous, ranging from the Berriasian to the Maastrichtian. The limit between Lower and Middle Cretaceous formations is not very clear, compared to the Middle and Upper Cretaceous limit.

Lower Cretaceous (Berriasian-Hauterivian) is characterized by the existence of benthic Foraminifera such as: *Marginulina seminota*, *Nodosaria* sp., *Dentalina communis* which have a lifespan until the Middle Cretaceous.

Middle Cretaceous is very determined by the association of : *Marginotruncana, Tristix excavata, Saracenaria schencki, Rotalippora appennica, Frondiculiaria archiaciana, Praeoglobotruncana stephani, Hedbergella madagascariensis, Globotruncana appenninica*. Also certified by the presence of the following Ostracods: *Pirileberis makatiniensis, Majungaella cf. pyriformis, Cytherelloidea ghotaruensis, Cytherelloidea ghotaruensis, Pontocyprella* sp., *Taracythere antakaranaensis,Malagasyella aff.rajendrai.*

Upper Cretaceous is distinguished by the diversification and abundance of planktonic foraminifera in relation to benthic foraminifera and Ostracods. It is also marked by the appearance of these species: *Archaeoglobigerina*, *Cibicides*. The Campanian is delimited by the following species: *Dentalina bradyensis*, *Globotruncana globigerinoides*. The Maastrichtian is not well defined because the existence of *Cidicides stephensoni*, *Lenticulina sternalis*, *Nodosaria s*p1, is not enough to define this stage. The distribution of Foraminifera and Ostracods in the Morafeno site define the Cretaceous from Berriasian to Maastrichtian.

5.2. Paleoecology

The paleoenvironment reconstitution and the deposit environment are mainly based on the microfossils ecology encountered in the site. The predominance of Foraminifera varieties is related to the way of life (microhabitat); they can be characteristic for an certain depth (PHLEGER, 1951), thus:

g. *Lagena*, the maximum appearance is between 30 and 205 m; g. *Marginulina* is located at less than 200 m.

g. *Nodosaria* likes shallow areas between 50 and 300 m;

g. *Saracenaria* is found at a depth of 110 m. It is characteristic of shallow and warm water;

g. *Hedbergella* predominates where the water depth is shallow and intermediate, 0-100m (outer neritic-coast);

g. *Heterohelix globulosa* 0-50 m (nearshore and middle neritic);

g. *Pullenia bulloide* is found in the marl layers from 100 to 200m depth, it is a form in the good conditions of oxygenation;

g. *Florilus* is characteristic of fined sediments in the infralittoral stage;

g. *Cibicides* having a muddy microhabitat in shallow waters with a weak tolerance to salinity and oxygen deficiency;

g. *Lenticulina* occurs in shallow waters, but adapts easily to different environmental changes;

g. *Globotruncana* likes a medium neritic zone up to the slope of 50 - 200 m depth. In fact, carinated taxa are abundant, considered among the forms of equilibrium linked to favorable conditions: open sea with great depth (MBANIJ.N, 2008). g. *Cytherella* inhabits the circalittoral zone.

The valves of Ostracods are fairly well preserved, indicating little hydrodynamism and little or no transport. The abundance of ornate forms suggests a carbonate-rich environment and thus a warm environment. The increase of calcium carbonate rate in the sediments is proportional to the microfauna diversification, because it ensures the microfossils survival by building up their test. Whereas, the character of the rock is also linked to the activity of organisms and comes from the minerals accumulation that they synthesize: the layer of sandy limestone in the MF3 level is the richest in microfauna (Foraminifera and Ostracods), in quantity and diversity of species, having a high calcium carbonate rate 67.62%.

5.3. Paleoenvironnement

Faunal association, geochemistry, and lithology allow inference the past environment in the site. The hypothesis reflects a photic zone, at an optimal temperature with a warm tendency and normal salinity. This zone is favorable for chemical precipitation (calcium carbonate and gypsum) and the environment belongs in the littoral zone. The sedimentation of gypsum limestone sand and sandy limestone evokes an environment of the internal platform for average to low energy, shallow, warm, infralittoral stage (Figure 15), at a depth of 0 to 200m.

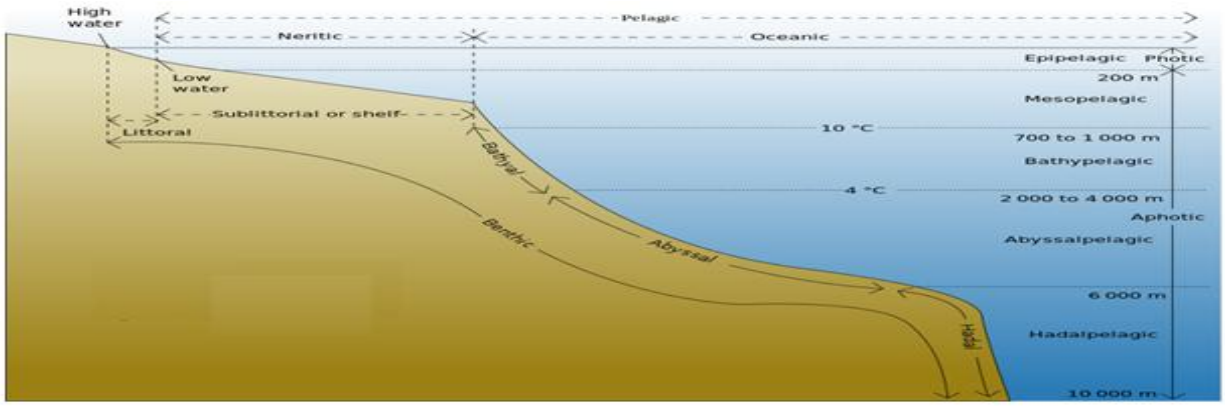


Figure 5: Oceanic division

5.4. Paleobiogeography

The spatial distribution of Foraminifera and Ostracods throughout the world (Table 6) is relative to geological phenomena that continue through the opening of the ocean

Table 6: Paleo-biogeographic distribution of Foraminifera and Ostracoda

Genus	Madagascar	Inde	Afrique	Mediterranean	Europe	South America	Ocean Indian
Lenticulina calcar	+				+		
Saracenaria	+				+		+
Amphicoryna scalaris	+				+		
Marginulina	+				+		+
Bolivina	+		+		+		
Pleurostomella	+				+		
Marginotruncana	+		+		+		+
Frondicularia archiaciana	+				+		+
Triloculina	+	+	+	+	+	+	+
Pullenia	+				+		
Gyroidinoides	+				+		+
Spiroloculina	+	+	+		+		
Nodosarella	+				+		
Nodosaria vertebralis	+		+				
Nodosaria mutabilis	+				+		
Dentalina communis	+				+		
Orbulina	+	+	+				
Heterohelix	+		+				
Globotruncana	+		+			+	+
Hedbergella	+		+			+	+
Cytherelloidea ghotaruensis	+	+					
Malagasyella aff rajendrai	+	+					
Pirileberis makatiniensis	+		+				
Majungaella cf. pyriformis	+		+			+	
Cytherella	+					+	
Pontocyprella	+	+					

Geographic distribution of microfauna in layers for the different stages is : species close to *Pirileberis makatiniensis* in India, *Majungaella* from the Senonian of Brazil, and in the Callovian layers of India, *Malagasyella* from the Coniacian to the Upper Albian in India, *Dentalina mutabilis* in the Middle Oxfordian of France, (BABINOT et al, 2009) may be due to the very high ocean expansion in the Cretaceous.

The affinity between Ostracods from Madagascar and India is remarkable in the Albian - Turonian interval. The hypothesis that Madagascar and India form a faunal province but also certainly presents dissimilarities. The similarity of microfossils between Africa and Madagascar as well as India (*Triloculina, Spiroloculina, Orbulina*) is dependent on their positioning within Gondwana.

In the Campanian - Maastrichtian, Foraminifera associations in the Southern Hemisphere are defined by 3 faunal provinces: Tethysian, Transitional and Southern. Tunisia, India, Libya, South-East France, constitute with Madagascar the Tethysian province. Where there is a similarity of microfaunal association, this is again due to oceanic expansion.

Conclusion

The micropalaeontological study in the Morafeno site allowed to determine the stratigraphic delimitations and the paleoenvironment of the Middle and Upper Cretaceous. This site contains 61 species of benthic Foraminifera, 20 species of planktonic Foraminifera and 10 species of Ostracods were observed. Among the microfossils met in this sector, the following species are amply characteristic of deposits for the Aptian-Campanian interval : Saracenaria schencki Pirileberis makatiniensis, Majungaella cf.pyriformis, Malagasyella Aff. Rajendrai, Rotalipora appenninica, Praeoglobotruncana stephani, Whiteinella, Globotruncana globigerinoides, Rotalipora brotzeni, Archaeoglobigerina, Dentalina bradyensis. Planktonic foraminifera are very abundant throughout the formation; this could be related to the rise in sea level. Geochemical analysis of sediments confirms that the rocks are constituted by a very high rate of SiO2 and CaO compared to the other elements, (MgO, Al2O3 and Fe2O3) which are generally weak or trace.

Therefore, the paleoenvironment of this site corresponds to a shallow marine environment in the restricted area, equivalent to a littoral zone, belonging to the infralittoral stage at about the photic zone from 0 to 200 m depth governed by a warm and arid climate. In the Lower and Middle Cretaceous, Madagascar and India constitute a faunal province but also there is a difference. In the Upper Cretaceous, the similarity of microfaunal association (Tethyan province) is due to oceanic expansion.

REFERENCES

1- BABINOT J.F., COLIN J.P., RANDRIANASOLO A., 2009. Ostracods of in theAlbian Middle Turonian from the Antsiranana region (North of Madagascar) : systématics, paleoecology et paleobiogeography. Geologie note book. Article 2009/01. 26p ;

2 - BESAIRIE H., 1965. Geology in the province of Diego Suarez. Documentation of géological office n° 171. géological service, Tananarive 194p ;

3 - BROOKS F.E, MESSINA A.R., CHARMATZ R. et RONAI L.E., 1968. Catalogue of index smaller Foraminifera. Cretaceous planktonic Foraminifera, Volume1; American museum of natural history New York; 500 p;

4 - COLLIGNON M., SIGAL J., et GREKOFF N., 1979. Albian and Cenomanian from the survey of Diego Madagascar and its Ammonite, planctonic Foraminifera and Ostracods faunas. Eclogae Geologica Helvetiae, base, vol.72 n°1 p 215-249;

5 - GREKOFF N., 1963. Contribution to the study of Ostracods in the Middle Mesosoic (Bathonian- Valanginian), Majunga basin, Madagascar, Ann. Géol. Madagascar, fasc. XXXIII, 167 p., 10 pl.

6 - GUSTAVO B., KLEINPELL, 1969. A stratigraphic sequence of benthonic smaller Foraminifera from the la Boca formation, Panama canal zone; contribution from the Cushman foundation for foraminiferal rechearch, vol XX, part 1, 43p;

7- HARTMANG. PURI H.S., 1974 Summary of neontological and paleontological classification of Ostracoda. Mitteilungen aus dem Hamburgishen Zoologishen Museum und Institut, Hamburg, Bd. 70, p. 7-73;

8- HOLBOURN A. L., KAMINSKI A.M., 1995. Valanginian to Barremian benthic Foraminifera from ODP site 766(Leg 123, Indian Ocean) research school of geological and geophysical sciences Birkbeck college and University college London. 54p;

9- HORNE D.J., COHEN A., et MARTENS K., 2002. Taxonomy, morphology and biology of Quaternary and living Ostracoda. In: HOLMES J.A et CHIVAS A.R (eds.), the Ostracoda: applications in Quaternary Research. Geophysical monograph 131, American geophysical Union, Washington D.C., p. 5-36;

10- LOEBLICH A.R., TAPPAN H., 1964. The Cambians and Foraminiferida, Volume 2; treatise on invertebrate Paleontology. The geological society of America and the University of Kansas. 900p ;

11- MBANI J.N., 2008. Micropaleontology and organic geochemistry Congolese coastal basin in the Upper Cretaceous: paleoecology of Foraminifera species and association indicating the the paleoenvironments of petroleum source rocks. Hesis Earth Science. Pierre Marie Curie-Paris VI University.95 figs, 42 tabs, 435 p.

12- PHLEGER F.B., et PARKER F.L.,1951. Ecology of Foraminifera, northwest gulf of Mexico. Part I. Foraminifera distribution. Part II. Foraminifera species. New York: Geological Society of America, volume 1, Memoir 46., 188 p;

13- RAKOTOVAO A.M., 2015. Paleontological map of Madagascar inventory and implementaton value of paleontological heritage. Thesis. Doct. University of Toulouse 486 P.

14- RANDRIANASOLO A., 1979. Micropaleontological and tectonic study of Betaitra valley- Nosy –Longo, Antsiranana region. Annales of University de Madagascar : Natural Sciences and Mathématiques series, 16, pp169-175.

15- RUFUS.M.B., 1898. The CRETACEOUS FORAMINIFERA of New Jersey, Washington government printing office, 116 P

16- UJIIE H., RANDRIANASOLO A., 1977.Cenomanian planktonic foraminifera from Diego- Suarez, northern Madagascar. Bull. Nat. Sci. Mus Tokyo (Geol. Paleontol.), 34, 183– 194. p185. Fig1.tabs1, 9 pls.