BIOSTRATIGRAPHY OF MAASTRICHTIAN BENTHIC FORAMINIFERA FROM THE BERIVOTRA SECTOR (MAHAJANGA BASIN), MADAGASCAR

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ABSTRACT

The physico-chemical analysis carried out in this work constitutes an important study of the marly sediments of the Maastrichtian. It is based on the analysis of 45 samples taken from the Berivotra sector (Miadana, Anembalemba and Berivotra) in the Mahajanga Basin. The area is very rich in macro and micro fossils. The present study considers the assembly of benthic foraminifera. The base of the outcrop is characterized by a small quantity of microfossils (Bolivinoides draco, Ammobaculites luckei, Textularia faujasi). The middle part constitutes a very fossiliferous benthic-pelagic zone (Marssonella oxycona, Lagena hispida, Glandulina parallela, Gavelinopsis acuta). The summit is represented by large foraminifera (Siderolites calcitrapoides, Laffiteina mengaudi). The Maastrichtian biostratigraphy of the Berivotra sector is represented by three biozonations from bottom to top: (Bolivinoides draco biozone, Gavelinella danica biozone and Siderolites calcitrapoides biozone). The Maastrichtian of the Mahajanga Basin seems quite homogeneous, with an association that evokes a marine environment with normal salinity and optimal temperature with warm influence. It indicates an external platform environment and the neritic zone, which is to say between the platform and the flexure of the continental slope (150m to 200m).

Keywords: *Biozonation, Berivotra, physico-chemical analysis, benthic foraminifera, Mahajanga Basin*

1. INTRODUCTION

The Maastrichtian extends over the whole Mahajanga Basin, which is entirely marine. It begins with a marine transgression overlaying the Campanian continental deposits. The microfossils, thanks to their abundance and their good preservation in the sediments, constitute an element of more precise dating. By their abundance in sedimentary deposits, their rapid evolution on the scale of geological time and their large geographical extension linked to their way of life, benthic foraminifera can be used in biostratigraphy. A large number of microfossils constitute excellent stratigraphic markers. Their dating can bring important elements for the knowledge of the chemistry and the dynamism of their environment of deposit. This work joins the planktonic foraminifera of the Berivotra sector (Mahajanga Basin). This article includes the study of the distribution of benthic foraminifera collected in a succession of sections located around the Berivotra sector. Three main sections (Miadana, Anembalemba and Berivotra) made it possible to establish the biostratigraphy of the benthic foraminifera of the Berivotra sector (Fig -1).

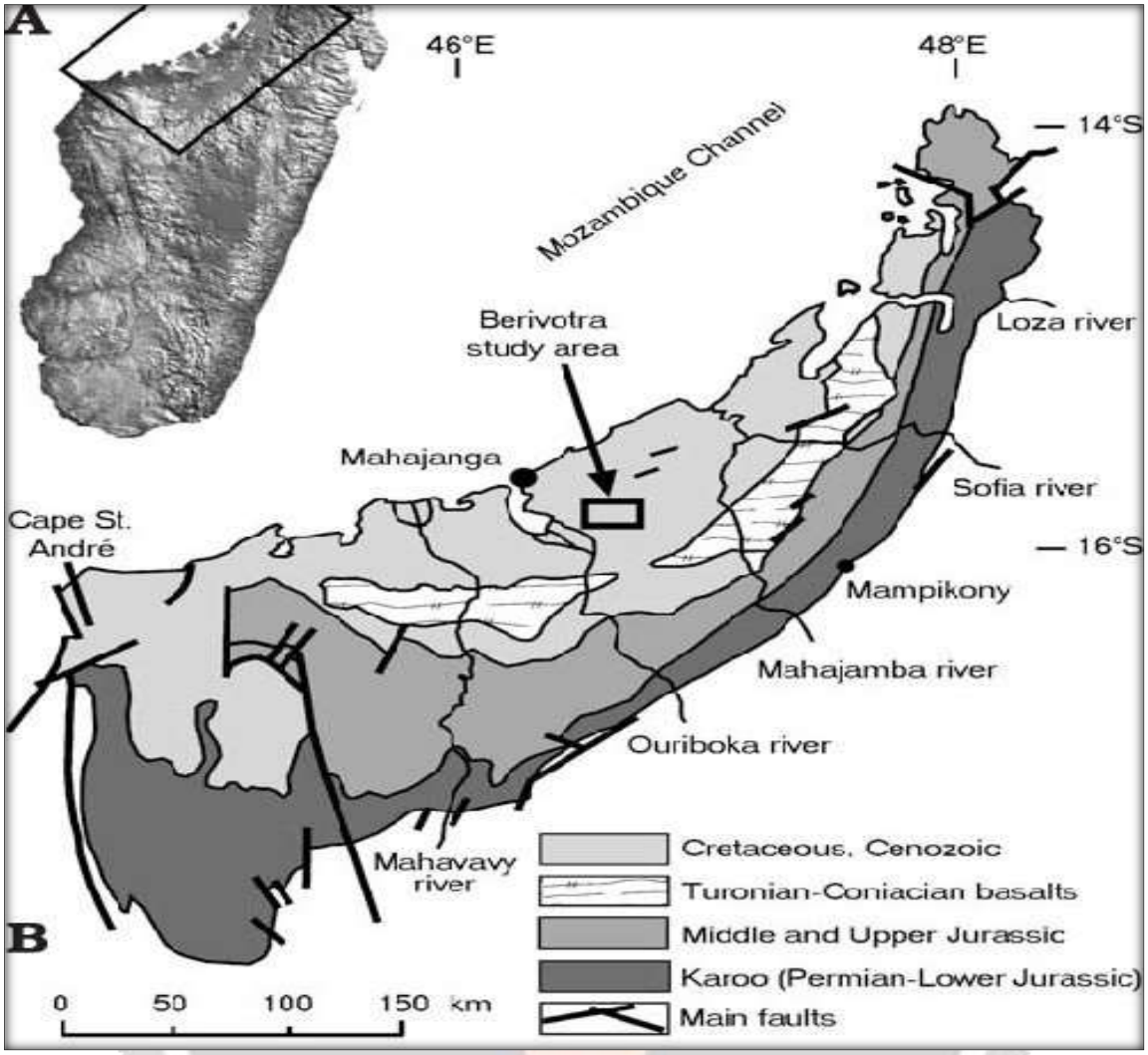

Fig -1: Localization of the study area (BD 100 FTM)

2. GEOLOGY

Many researchers worked on the Maastrichtian of Mahajanga (Fig -2). In this study, we considered the work of be [12], [6], [9], [18], [19], and [1].

The Berivotra sector (Fig -2) is made up of sedimentary deposits aged Upper Cretaceous which are from bottom to top:

- The Maevarano Formation (Campanian) made up of continental sandstone;
- The gray marls of the Berivotra Formation (Maastrichtian).

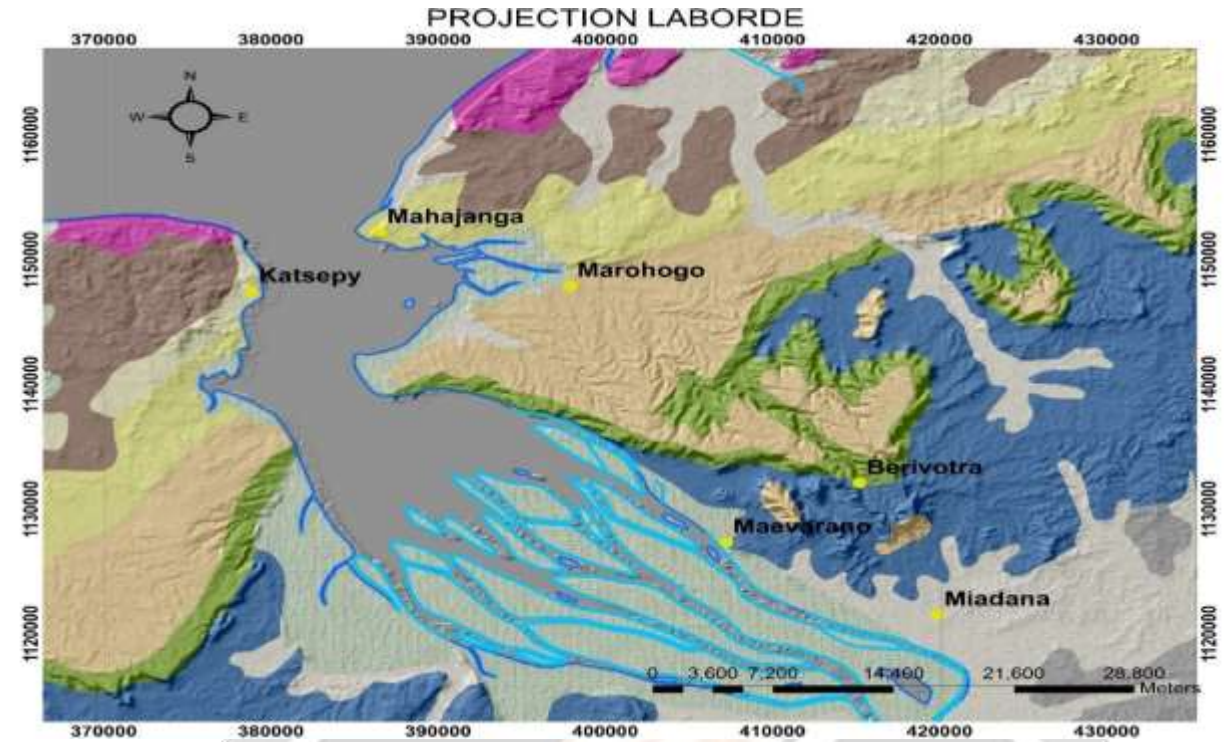

Fig -2: Geological map of the Mahajanga Basin (BD 500 FTM)

3. MAEVARANO FORMATION (CAMPANIAN)

The Campanian or Maevarano series [6] or Maevarano Formation [19] has been studied near the village of Berivotra. It is represented by continental deposits consisting of fine to coarse sandstone, reddish clayey sandstone and obliquely stratified sandstone levels. This Formation is made up of three Members [19] which are from bottom to top: Masorobe, Anembalemba and Miadana.

- **Masorobe Member**

The Masorobe sector is located around Berivotra. The typical section outcrops south of Masorobe with a thickness of 80m, and is considered the base of the Maevarano Formation. The Masorobe Member is characterized by a red color. It is made up of coarse sandstone, occasionally intercalated by fine sandstone, silty sandstone and hard clay, poor in fossils.

- **Anembalemba Member**

The Anembalemba sector is located east of the village of Berivotra. The typical section outcrops along the western part of the AP4. The Anembalemba Member is characterized by two very distinct facies: Facies 1 and Facies 2 which are, from bottom to top:

- Facies 1, made up of fine to coarse white colored sandstones with oblique stratifications, not very fossiliferous;
- Facies 2, formed by fine-grained and coarse-grained olive-green sandstone clays, rich in vertebrate fossils. In general, it has a massive structure. Load structures are relatively normal. The thickness of the layers varies from one outcrop to another.

- **Miadana Member**

The Miadana sector is located 4km south-east of the village of Berivotra (on the national road AP4, PK 508.4) on isolated hills. The Miadana Member is 24.5m thick. It is represented by heterogeneous sandstones, fine to coarse, white and gray green with red base, rarely fossilized.

4. BERIVOTRA FORMATION (MAASTRICHTIAN)

The Berivotra Formation is the equivalent of the Maastrichtian marls of BESAIRIE (1972). It is completely marine. It consists of homogeneous sediments of marls and silty clays of olive-green color. The Berivotra Formation is very fossiliferous, including Brachiopods (*Crania costata*), Bryozoans (*Lunulites pyripora*), Lamellibranchs (*Pycnodonta vesicularis, Alectryonia ungulata, Gryphaeostrea sp.*), Echinoderms (*Hemiaster sp.*), Gastropods (*Turritella sp.*), rare Ammonites (*Baculites sp.*) and Selachian teeth. The thickness of the marly levels of the Berivotra Formation tends to reduce from the northwest to the southeast of the Mahajanga Basin [19].

5. MATERIALS AND METHODS

Sampling and processing

The material studied comes from sampling carried out in the marly deposits of the Berivotra sector (Mahajanga Basin). Prospecting was done around the sector because the majority of outcrops are of poor quality. The coordinates were taken by GPS. Sampling and cutting were carried out in Miadana, Anembalemba and Berivotra (Fig -3).

Physico-chemical analyzes were carried out on these loose sediments (washing with increasing mesh, monitoring of sorting and determination of species). Observations of the microfossils were made using a binocular magnifying glass. The determinations of taxa (family, genus and species) were based on the literature.

6. RESULTS

The Maastrichtian of the Berivotra sector is made up of homogeneous sediments of olive-green marls. The Berivotra Formation is very fossiliferous in macrofauna such as: Brachiopods (*Crania costata*), Bryozoans (*Lunulites pyripora*), Lamellibranchs (*Pycnodonta vesicularis, Alectryonia ungulata, Gryphaeostrea sp.*), Echinoderms (*Hemiaster sp.*), Gastropods (*Turritella sp.*), rare Ammonites (*Baculites sp.*) and Selachian teeth; and in microfauna: Foraminifera, Ostracods and Bryozoa.

6.1. Lithology

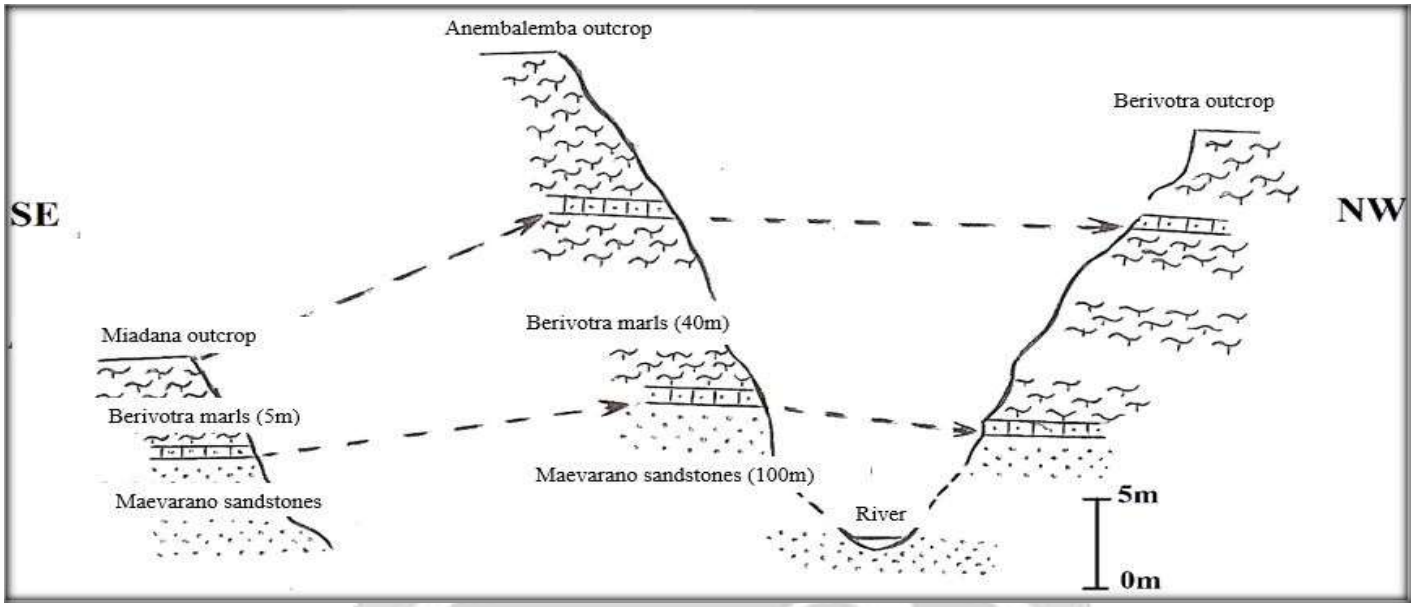

Fig -3: Sections of Miadana, Anembalemba and Berivotra (RAHANTARISOA, 2007)

The Anembalemba section was taken as the reference section. It is framed at the base by the continental sandstones of the Maevarano Formation (Campanian) and at the top by the marly limestone of the Betsiboka Formation (Danian). Therefore, it is considered the most complete of these three sections (Fig -3).

6.2. Microfossils

The marly sediments contain an association of diverse and abundant microfauna whose conservation is more or less complete. These faunal compositions vary according to the time of the sediments which characterize them.

6.2.1. Foraminifera

The determination or the comparison of the various forms observed were carried out using the descriptions and holotype representations. Many species are left in open nomenclature because they only show variations from known forms.

The classification of Foraminifera was established on the morphological characters of the test. The classification adopted is that of LOEBLICH & TAPPAN, (1964).

6.2.2. Benthic Foraminifera

The observation highlights the predominance of hyaline Foraminifera over agglutinated Foraminifera. The importance of Foraminifera with hyaline and agglutinated test is remarkable at the level of each section (Fig -4).

6.2.3. Systematic determination

Order FORAMINIFERIDA
Super family LITUOLACEA from Blainville, 1825
Family LITUOLIDAE from Blainville, 1825
Genus *Ammobaculites* Cushman, 1910
Ammobaculites lueckei Cushman and Hedberg, 1941
Synonymy:
Ammobaculites lueckei Cushman and Hedberg, 1941, p 83, pl 21, fig. 4.
Haplophragmium lueckei Cushman and Hedberg, Loeblich and Tappan, 1964, p. c 244.
Description: Clumped, loose, broad test. Spiral initial portion, followed by a uniseriate stem of almost constant width. Depressed, distinct sutures. Terminal opening, rounded. Surface decorated with agglutinate.
Deposit: marls of Berivotra
Stratigraphic distribution: Maastrichtian

Family TEXTULARIIDAE Ehrenberg, 1838
Genus *Textularia* Ehrenberg, 1838
Textularia faujasi Reuss, 1861
Synonymy:
Textularia faujasi Reuss, Sitz, Akad.Wiss.Wieu, vol.44, pl.1, 1861.

Gaudryina faujasi Cushman, contrib Cushman Foram.Res, vol. 8, p.91, 1932
Description: Agglutinated, broad, elongated test, triseriate initial portion, biseriate elongated part of increasing size. Indistinct suture. Rectangular opening on the last box. This species is present in all levels, abundant in levels II.
Deposit: marls of Berivotra.
Stratigraphic distribution: Maastrichtian

Family ATAXOPHRAGMIIDAE Schwager, 1877
Genus *Dorothia* plummer, 1951
Dorothia oxycona Reuss, 1861
Synonymy:
Gaudryina oxycona (Reuss), 1860, p.229, pl.12. Fig.3.Cushman and Church, 1929, p.501, pl.36, fig.3-4.
Marssonella oxycona (Reuss), Bandy, 1951, p.492, pl.72, fig.8 – Martin, 1964, p.56, pl.3, fig.14.
Dorothia oxycona (Reuss), Trujillo, 960, p.309, pl.44, fig.5 –Loeblich and Tappan, 1964, p.c 275, 1845.
Marssonella trochus (d'Orbigny), Graham and Church, 1963, p.21, pl.1, fig.6.
Description: Agglutinated, conical test, initial trochospiral portion, formed of 4 to 5 cells, followed by a biseriate shaft. The suture is quite distinct. The surface is adorned with fine agglutinate. Terminal opening, located at the base of the last chamber. This species is found in all levels of the marl formation
Deposit: marls of Berivotra.
Stratigraphic distribution: Maastrichtian
Super family NODOSARIACEA Ehrenberg, 1838
Family NODOSARIIDAE Erhenberg, 1838
Genus *Nodosaria* Lamarck, 1812
Nodosaria hispida Reuss, 1861
Synonymy:
Lagena hispida Reuss, 1863, p.335, pl.6, fig.77-79 - Cushman, 1946, p.93, pl.39, fig. 13- Cushman, 1949, p.6, pl.3, fig. 8 - Hagn, 1953, p.68, pl.2, fig. 31 – Pozaryska, 1957, p.47, pl.2, fig. 8.
Description: Calcareous test, elongated. The lodges are sub-globose, quite distinct, of increasing size. The suture is quite distinct, depressed. The surface is decorated with longitudinally arranged and continuous ribs. Radiated terminal aperture. This species differs from *Nodosaria septemcostata* Geinitz by its robust size and well-separated chambers. It is present in all levels of the section.
Deposit: marls of Berivotra
Stratigraphic distribution: Maastrichtian

Genus *Lagena* Walker & Jacob in Kanmacher, 1798
Lagena acuticosta Reuss
Synonymy:
Lagena acuticosta Reuss, 1862, p. 305, pl.1, fig. 4 – Cushman, 1946, p. 94, pl. 39, fig. 14 -15
Description: Sub-globose calcareous test, surface decorated with 11 ribs arranged longitudinally. Terminal opening. This species is present in levels II of the gypsum marls.
Deposit: marls of Berivotra
Stratigraphic distribution: Maastrichtian

Family POLYMORPHINIDAE from Orbigny, 1839
Subfamily RAMULININAE Brady, 1884
Genus *Ramulina* Jones, 1875
Ramulina globotubulosa Cushman
Synonymy:
Ramulina globotubulosa Cushman, 1938b, p.44, pl.7, fig.16.
Description: Calcareous test, free, globular lodge with tubular extensions. Finely perforated surface. The opening is at the end of the tubular extensions. This species is present in level II, Berivotra marls.
Deposit: marls of Berivotra
Stratigraphic distribution: Maastrichtian

Super family BULIMINACEA Jones, 1875
BOLIVINITIDAE family from Orbigny, 1839
Genus *Bolivina* from Orbigny, 1839
Bolivina incrassata Reuss
Synonymy:

Bolivina incrasssata Reuss, 1851, p.29, pl. 5, fig. 13. – Cushman and Campbell, 1935, p.73, pl.11, fig. 10. – Hofker, 1957, p.28, fig.282-286, 291. – Graham and Church, 1963, p.52, pl.5, fig.26. – Martin, 1964, p.90, pl.11, fig 14. – McGugan, 1964, p.942, pl.150, fig.22-23.
Description: Limestone test, elongated, biseriate, subacute to acute periphery. The lodges are wide in increasing size, slightly arched and domed. Well distinct suture. Smooth, finely perforated surface. Elongated opening at the base of the last cell. This species is present in all levels.
Deposit: marls of Berivotra
Stratigraphic distribution : Maastrichtian

Genus *Bolivinoides* Cushman, 1927
Bolivinoides draco (Marsson)
Synonymy:
Bolivina draco Marsson, 1878, p.157.pl.3, fig.25.
Bolivinoides rhomboidea Cushman, 1927, p.90, pl.12, fig.10.
Bolivinoides draco draco (Marsson), Hiltermann and Koch, 1950, p.598, fig.1, 72-73, 2 – 4, 52 -54, 58 – 60, 5, 53, 69-70. –Edgell, 1954, p.73, pl.13, fig.1 -3. –Reiss, 1954, p.155, pl. 29, fig.1-3.-Van Hinte, 1963, p.106, pl.14, fig.3.
Bolivinoides draco (Marsson), Montanaro Gallitelli, 1957, p.145, pl. 33, fig.13-Eternod Olvera, 1959, p.80, pl.2, fig.10, 12.
Description: Calcareous, rhomboidal, compressed test. Biseriated chamber, low, wide and oblique. Sutures indistinct, except on the outer margin. The surface is adorned with highly developed tubercles arranged longitudinally. Terminal aperture wide, interior-marginal.
Deposit: marls of Berivotra
Stratigraphic distribution: Lower Maastrichtian

Family ANOMALINIDAE Cushman, 1927
Subfamily ANOMALININAE Cushman, 1927
Genus *Gavelinella* Brotzen, 1942
Gavelinella nacatochensis Cushman
Synonymy:
Planulina mascula Bandy, 1951, p.506, pl.74, fig.8.–Martin, 1964, p.107, pl.16, fig. 7.
Eponides goudkoffi Trujillo, 1960, p.333, pl.48, fig. 6.
Gyroidina sp. Graham & Church, 1963, p.59, pl.6, fig. 23.
Gyroidina goudkoffi (Trujillo), Martin, 1964, p.96, pl.13, fig. 3.
Eponides sp. cf.simplex (White), McGugan, 1964, p.944, pl.151, fig.7.
Eponides sp. cf. beisseli Schijfsma, McGugan, 1964, p.944, pl.151, fig.4.
Description: Calcareous test, trochospiral, convex spiral face, strongly convex umbilical face, 4 to 7 cells on the last turn of the whorl, of increasing size, curved, limbate on the spiral face. Finely perforated smooth surface. Interior-marginal opening.
Deposit: marls of Berivotra
Stratigraphic distribution : Maastrichtian.
Genus *Gavelinella* Brotzen, 1942
Gavelinella danica Cushman
Synonymy:
Planulina mascula Bandy, 1951, p.506, pl.74, fig. 8, –Martin, 1964, p.107, pl.16, fig.7.
Planulina nacatochensis Cushman, 1938b, p.50, pl.8, fig.9, –McGugan, 1964, p.946, pl. 152, fig.3.
Planulina sp.cf. P.mascula Bandy, Graham and Church, 1963, p.66, pl.8, fig. 3.
Description: Calcareous test, trochospiral, partially evolving spiral face, clearly visible initial lodge, involute umbilical face. 9 to 11 boxes on the last lap. Oblique suture. Smooth surface. Interior-marginal opening.
Deposit: marls of Berivotra
Stratigraphic distribution: Middle Maastrichtian

Super family ROTALIACEA
Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIINAE Galloway, 1933
Genus *Laffitteina* Marie, 1945
Laffitteina mengaudi Astre, 1923
Synonymy:
Laffitteina bibensis n. gen., n.sp.- P. Marie, 1945, p.419-434,
Laffitteina conica n. sp.- C.W. Drooger, 1952, p.100, pl.16.
Laffitteina bibensis Marie C.W. Drooger, 1952, p.99-100, pl.16.

Laffitteina marsicana Farinacci P.L., J.P. Colin, 1975, p.112, pl.1-2.
Laffitteina mengaudi (Astre), P.L. Blancs, and J.P. Colin, 1975, p.116-118, pl.1-2.
Laffitteina marsicana Farinacci, J.J. Fleury, 1973, p.125-127.
Description: Calcareous test, lenticular or domed, presenting a rounded convex face, never keeled. Only the last winding tower has visible partitions. They are underlined by alternate perforations on either side of the trace of their insertion on the wall. Oblique basal slit opening extending towards ventral knob. This species is found in the upper levels of the Berivotra marls.
Deposit: marls of Berivotra
Stratigraphic distribution: Upper Maastrichtian

Family CALCARINIDAE Schwager, 1876
Genus *Siderolites* Lamarck, 1801
Siderolites calcitrapoides Lamarck, 1801
Synonymy:
Siderolites calcitrapoides Lamarck-Visser, 1950a, p.275, pl.7, Figure.16, pl.10, fig.4 -5.
Siderolites calcitrapoides Lamarck-Hofker, 1966, p.142, pl.21, fig.58-60, pl.24, fig.136, pl.28, fig.46, pl.33, fig.76-78.
Siderolites calcitrapoides Lamarck-Blanc, 1973, p.130, pl.16, fig.1.
Siderolites calcitrapoides Lamarck –Neumann, 1986, p.130-131, pl.1, fig.15, pl.2, fig.12, pl.3, fig.8.
Description: The test is planispiral, involute, globular, with more or less developed arms and ornamentation consisting of granules distributed over the entire surface of the test. *S. calcitrapoides* can be confused with *S. praecalcitrapoides* due to the presence of arms. In general, the size of *S. calcitrapoides* is large, the arms are more numerous (4-8).
Deposit: marls of Berivotra
Stratigraphic distribution: Upper Maastrichtian

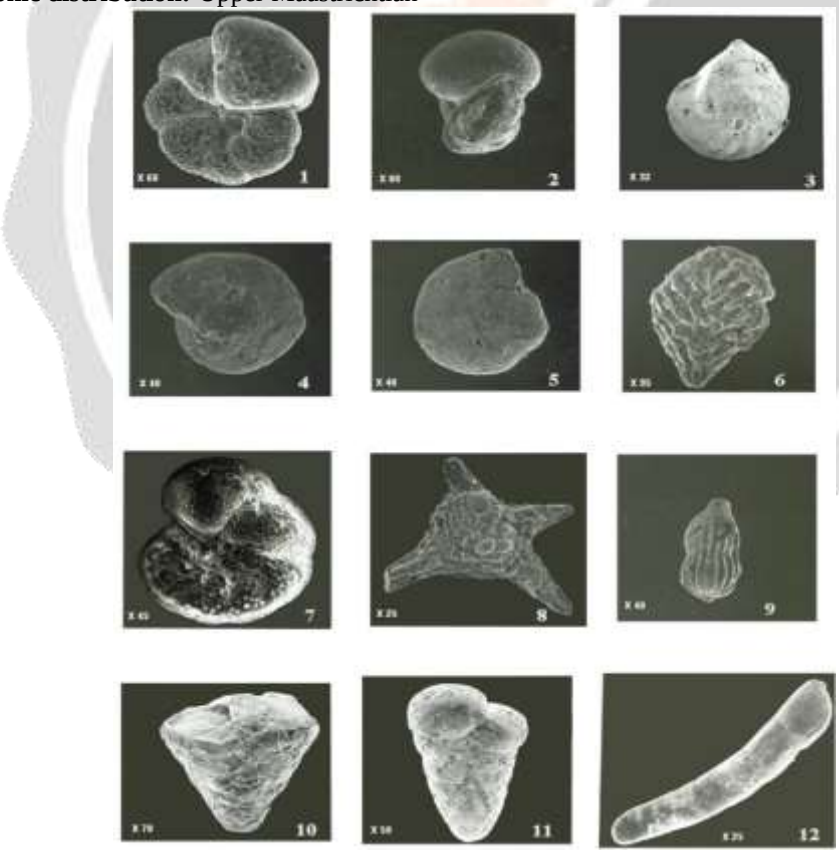

Fig -4: Benthic foraminifera from the Maastrichtian of the Berivotra area,1,2 *Gavelinella danica*,3 *Lenticulina sp., 4,5 Gavelinopsis sp., 6 Bolivinoides draco, 7 Cibicides sp.,8 Siderolites calcitrapoïdes,9Nodosaria sp., 10 Marsonella sp.,11 Dorothia oxycona, 12 Dentalina basiplanata* (RAHANTARISOA, 2007)

6.3. Biostratigraphy

Benthic foraminifera are of little biostratigraphic interest than planktonic forms, whereas the samples taken revealed their presence in large quantities. The biostratigraphic scales established from these benthic foraminifera only have local value for the moment (Fig -5).

Proposed biozonation

Benthic foraminifera-based biozonation is strongly facies-related. Benthic foraminifera from Madagascar are very common species because they are found in many countries. The use of biozonation in benthic foraminifera, at the regional or local level, is based on their macrofauna equivalents which have a good biochronostratigraphic resolution power. Taking into account their importance in terms of species and quantity, the use of benthic foraminifera as dating elements can give reliable results.

Few studies on the biozonation of benthic foraminifera from the Maastrichtian have been carried out so far. In this study of the Maastrichtian, we were inspired by the work of KOCH (1977) on benthic foraminifera. Thus, according to the faunal composition, the Maastrichtian was characterized and subdivided into three biozones. From bottom to top, we propose:

- ***Bolivinoides draco Biozone***

Age: Lower Maastrichtian

Synonymy:

- For Benthic Foraminifera:

Zone with *Neoflabellina reticulata* Koch (1977).
Zone with *Bolivinoides miliaris* Barr (1970).

Synonymy:

- For planktonic Foraminifera:

Zone with *Globotruncana lapparenti tricarinata* Bolli (1957).
Zone with *Globotruncana tricarinata* Wonders (1980), Randrianasolo (1983), Barr (1972).
Zone with *Globotruncana falsostuarti* Bellier (1982), Robanszynski et al. (1984), Sigal (1977).
Zone with *Globotruncana stuartiformis* Postuma (1971).
Zone with *Rugotruncana subcircumnodifer* Premolisilva & Bolli (1973).
Zone with *Globotruncana aegyptiaca* Caron (1985), Shahin (1992).
Zone with *Rosita contusa* Abramovich et al. (2002).

The *Bolivinoides draco* biozone is characteristic of the Upper Maastrichtian of Libya [3], while it characterizes the Lower Maastrichtian of Berivotra. Present at Berivotra and Anembalemba, over a thickness of about 5m, it is absent in the Miadana section.

Bolivina incrassata and *Gavelinopsis involuta* species persist to the top of the formation.
Among the planktonic Foraminifera: *Globotruncana stuartiformis, Globotruncana ventricosa, Globotruncana linneiana, Globotruncana falsostuarti*

Deposit: Anembalemba and Berivotra, absent in Miadana.

- ***Gavelinella danica* Biozone**

Age: Middle Maastrichtian

Synonymy:

- For Benthic Foraminifera:

Zone with *Bolivinoides draco* Barr (1970), Koch (1977).

Synonymy:

- For planktonic Foraminifera:

Zone with *Globotruncana contusa* Haq et al. (1987).
Zone with *Globotruncana gansseri* Caron (1985), Berggren et al. (1995), Bellier (1982).
Zone with *Rugotruncana gansseri* Randrianasolo (1986).
Zone with *Gansserina gansseri* Brönnimann (1952), Shahin (1992).

In Berivotra and Anembalemba, the zone has a thickness of 27m and 3m in Miadana.
The common forms of this biozone are: *Gavellinella danica, Daviesina fleurausi, Neocorbina sp, Gavellinella umbilicata, Cibicides bosqueti, Dentalina basiplanata, Lagena sulcata, Lenticulina intermedia, Nodosaria filiformis, Frondicularia linguiformis, Dorothia pupoides, Marssonella oxycona.*
Calcareous forms are very abundant compared to arenaceous forms. The association of planktonic foraminifera is made up of: *Globotruncanita angulata, Gt. insignis, Contusotruncana contusa, Rugotruncana reicheli, Rugotruncana rotundata, Planoglobulina brazoensis, Pseudoguembelina cornuta.*

Deposit: Anembalemba, Berivotra, Miadana.

- ***Siderolites calcitrapoïdes* Biozone**

Age: Upper Maastrichtian.
Synonymy:

- For Benthic Foraminifera:

Zone with *Bolivinoides draco* Barr (1970).

Synonymy:

- For Planktonic Foraminifera:

Zone with *Racemiguembelina fructicosa* Koch (1977)
Zone with *Abathomphalus mayaroensis* Caron (1995), Berggren et al. (1995), Pessagno (1967), Barr (1972), Govindan (1972).
The thickness of the biozone is about 5m at Anembalemba and Berivotra and 2m at Miadana. The association of benthic foraminifera is made up of: *Siderolites calcitrapoides, Siderolites laevigata, Laffiteina mengaudi.*
For planktonic foraminifera, we note the presence of: *Racemiguembelina fructicosa, Abathomphalus mayaroensis, Contusotruncana contusa, Pseudoguembelina palpebra.*
Deposit: Anembalemba, Miadana, Berivotra.
The biozonation of benthic foraminifera from the Maastrichtian of Berivotra made it possible to establish a distribution of these microfossils (Table -1).

Table -1. Comparison between proposed biozonation with that of other authors, for benthic foraminifera from the Maastrichtian

<table>
<tr><th>STAGE</th><th>SUB STAGE</th><th>PRESENT STUDY (2022)</th><th>SUB STAGE</th><th>KOCH (1977)</th><th>BARR (1970)</th></tr>
<tr><td rowspan="3">MAASTRICHTIAN</td><td>UPPER</td><td rowspan="2">Siderolites calcitrapoides
or
Laffiteina mengaudi</td><td rowspan="2">UPPER</td><td>Racemiguembelina fn.
or
Pseudotextularia elegans</td><td rowspan="3">Bolivinoides draco</td></tr>
<tr><td>Gavelinella Danica</td></tr>
<tr><td>MIDDLE</td><td>Gavelinella danica</td><td rowspan="2">LOWER</td><td>Bolivinoides draco</td></tr>
<tr><td>LOWER</td><td>Bolivinoides draco</td><td>Neoflabellina reticulata</td><td>Bolivinoides miliaris</td></tr>
</table>

The Maastrichtian of the Berivotra area is characterized by three substages: Lower, Middle and Upper, which correspond respectively to the *Bolivinoides draco, Gavelinella danica* and *Siderolites calcitrapoides biozones.*

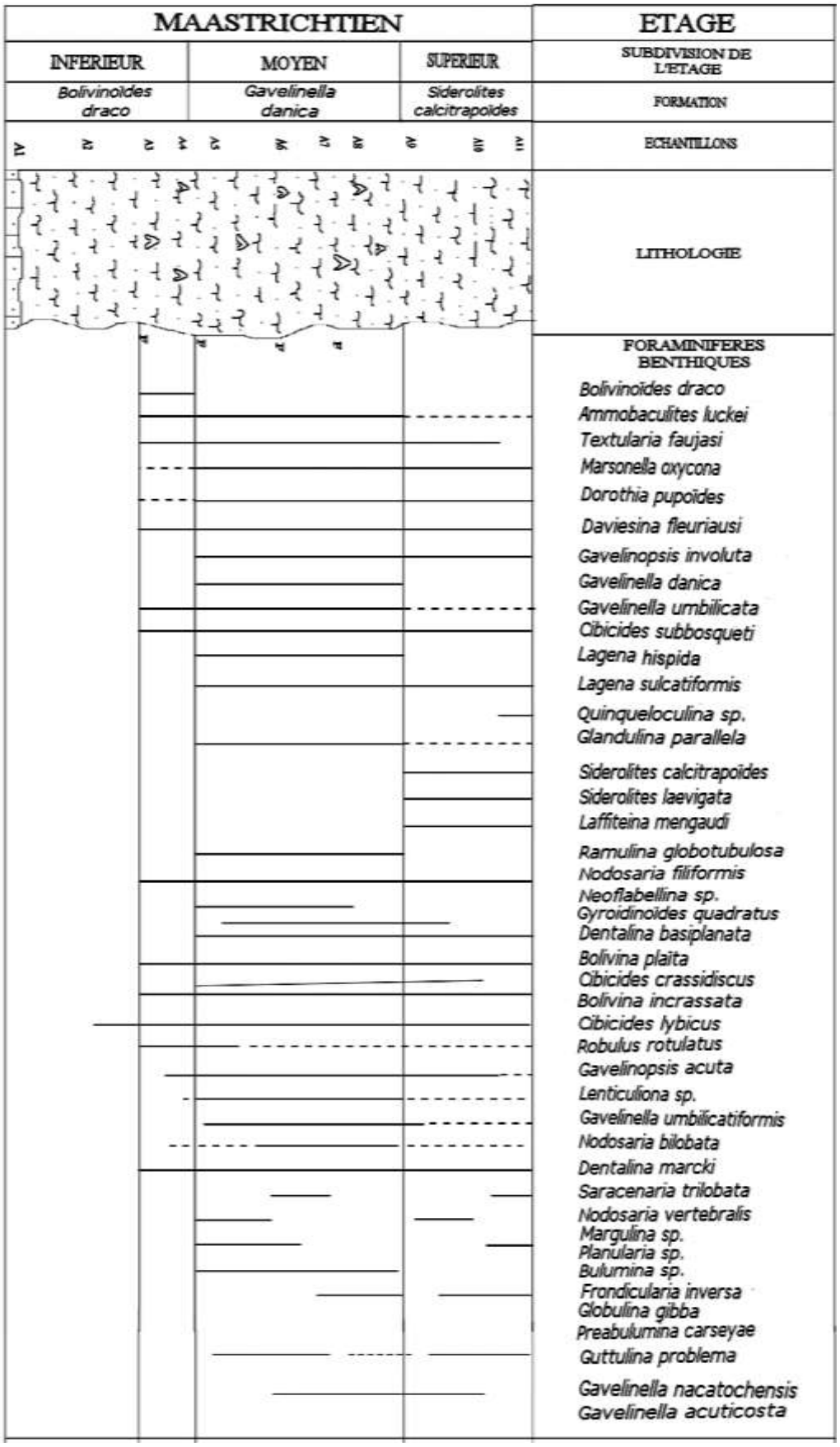

Fig -5: Distribution of benthic foraminifera species in the Maastrichtian of the Berivotra area

7. CONCLUSIONS

The Maastrichtian of the Berivotra area (Miadana, Anembalemba and Berivotra) of the Mahajanga Basin is entirely marine. It is made up of marl deposits over a thickness of 40m at the level of Anembalemba (reference section).

The physico-chemical analyzes of the sediments collected made it possible to identify the different groups of microfossils (Foraminifera, Ostracods and Bryozoa). Foraminifera are very abundant from a quantitative and qualitative point of view in all levels. The relative age was obtained by the biozonation of planktonic foraminifera ([18] and [1]) and calcareous Nannofossils [17].

The biostratigraphy of benthic foraminifera allowed the subdivision of the Maastrichtian into three well-defined biozones, from bottom to top: *Bolivinoides draco* biozone (Lower), *Gavelinella danica* biozone (Middle), *Siderolites calcitrapöïdes* biozone (Upper). The subdivision of the Maastrichtian into three biozones corresponds to the three substages of the Maastrichtian (Lower, Middle and Upper).

8. REFERENCES

[1] Abramovich S., Keller G., Adatte T., Stinnesbeck W., Hottinger L., Stueben D., Berner Z., Ramanivosoa B., Randriamanantenasoa A.,2002. Age and paleoenvironnement of the Maastrichtian to Paleocene of the Mahajanga basin, Madagascar: a multidisciplinary approach. Marine micropaleontology, vol.47, 70p

[2] Bandy O., 1967. Cretaceous planktonic foraminiferal zonal. Rev. Microp.vol.13, nº1, pp.1-31.

[3] Barr F.T., 1972. Cretaceous biostratigraphy and planktonic Foraminifera of Libya. Microp, vol.18, nº1, p.1-46, 10pls.

[4] Bertels, 1975. Upper Cretaceous (Middle Maastrichtien) Ostracoda of Argentina. Microp. vol.21, nº1, p.1-13, pls.1-3.

[5] Bésairie H. ,1972. La géologie de Madagascar. Tome I : Les terrains sédimentaires. Annales Géol. Madagascar, fasc.nºXXXV, pl.89, 463p.

[6] Bignot G. ,1982. Les microfossiles. Bordas, Paris, 211p.

[7] Bignot G., 1992. Une association de Foraminifères du récif Montien de Vigny. Considérations sur la paléogéographie Dano-Montienne du Nord –Ouest européen. Rev. Microp., vol.35, nº3, pp.179-196.

[8] Brood K., 1976.Cyclostomatous Bryozoa from Maastrichtian of Majunga basin, Madagascar. Geobios, nº9, fasc.4, p.393-423, tabl.2, pls.7.

[9] Collignon M., Sigal J., 1955. Première note sur quelques Foraminifères Crétacés supérieurs de Madagascar. C.R. Somm. Soc.géol. Fr., p.291-293.

[10] Dingle R.V., 1981. The Campanian and Maastrichtian Ostracods of South East Africa. Ann. S. Afri. Mus., vol.85, part1, 81 figs, 20 tabs.

[11] Fournie L., 1965. Recherches de gisements stratiformes à Madagascar (phosphate). BRGM, 24p.

[12] Koch W. (1977). Biostratigraphie in der oberkreide und taxonomie von Foraminifera. *Geol.Jb A 38:11-23.*

[13] Kouyoumontzahis C., 1992. Le plateau continental gabonais. Associations de Foraminifères benthiques. Rev.Microp., vol.35, nº4, pp.271-280.

[14] Loeblich A.R., Tappan H., 1964. Treatise on Invertebra paleontolology :Protista.Geol.Soc.Amer. Univ. Kansas Press, vol.2, pp.511-900.

[15] Papini M., Benvenuti M., 1998. Lithostratigraphy,sedimentology and facies architecture of the Late Cretaceous succession in the central Mahajanga Basin, Madagascar.

[16] Perch-Nielsen K, 1985. Mesozoïc calcareous nannofossils in plankton stratigraphy.Bolli, Saunders et Perch-Nielsen editors, Cambridge University Press, pp.427-554.

[17] Randrianasolo A., 1986. Etude stratigraphique et micropaléontologique des bassins sédimentaires malgaches situées au Nord de Betsiboka de l'Albien moyen à la limite Crétacé-Tertiaire. Thèse Doctorat d'Etat, Univ.Aix-Marseille, 35pls, 349p.

[18] Rogers R., Hartman J.H., Krause D., 2000. Stratigraphic Analysis of Upper Cretaceous Rocks in the Mahajanga Basin,Northwestern Madagascar:Implications for Ancients and Modern Faunas.The journal of geology.