CHAPTER - 4

BIOSTRATIGRAPHY

In chapters 2 and 3, on the basis of field and sedimentological characteristics, details regarding various litho facies present within Maniyara Fort Formation are described. In this chapter, the paleontalogical studies i.e. faunal contents of the formation have been examined in relation to specific facies types and their regional as well as vertical distribution. Microfossil groups studied include larger foraminifera, smaller foraminifera, planktonic foraminifera and ostracoda. Besides, an attempt has also been made to describe the nannoplankton fauna. Selected megafossils such as coral, bryozoa, echinoids, gastropods, pelecypods etc. are described briefly.

4.1 METHODOLOGY

In order to disintegrate the fossils embedded in rocks, consolidated sediments were granulated by agate mortar and crusher, 50 gms. of the material was soaked in water and then put into, equal volume of hydrogen peroxide and concentrated Ammonia solution, and boiled. This was followed by QUAT-O (mildly acidic regent) solution treatment for 12 hours. After washing, the same was boiled in water for 2 hrs, with 20 gms of washing soda and subjected to ultrasonic sound for 2 minutes. After washing over 200 mesh, residue was dried in a oven at 100° C. Each residue was subsequently sieved after coning and quartering method. Microfauna occuring in the 30, 60, 100 and 150 mesh fractions were hand picked, identified and counted, using binocular microscope.

This method was found inadiquate to obtain the fauna from hard and massive limestone samples. For their study thin sections were prepared by grinding the rockchips successively over 100, FFF and 600 carborundum powder.

Additionally, smear-slides were prepared for nannoplankton, studies.

4.2 VERTICAL FAUNAL DISTRIBUTION

As stated earlier, total faunal content of larger foraminifera, smaller foraminifera, and planktonic foraminifera, ostracoda and megafossils were studied. Nannoplankton investigations are described seperately. The state of preservation, size, colour and nature of test, relation of test with the matrix and with other specimens were taken into account. For the interpretation of paleobathymetry and paleoecology, principles adopted by Butt, (1981), for similar investigations to decipher the bathymetry of Cretaceous of W. Morocco, were followed. Foraminiferal number, species diversity and gross percentage ratio of major faunal groups were calculated and were plotted in pie diagram. Foraminiferal number is the number of foraminifera in one gram of dry sediment (Bandy and Arnal, 1960).

For the identification of the recovered fauna classic work(of 'Adams (1984,86); Adams et. al. (1986); Sirotti (1982); Drooger (1986) van der Vlerk (1963, 68); Bolli and Saunders (1985) and ' Berggern et. al. (1985) is consulted.

4.2.1 Ratipal Section

The base of the Ratipal section (Figure 4.1) is characterised olive green coloured, oval shaped glauconite pellets, by few miliolids, dwarf boliviniids and small, smooth shelled ostracods. Rich larger foraminiferal assemblage is recovered from the overlying silty and argillaceous dolomite sequence. It mainly comprises of reticulate Nummulites such as N. fichteli Michelotti, N. intermedius, N. clipeus Nuttall, Heterostegina kohili and few Operculina. Both macrospheric and microspheric tests of Nummulites are present. Pararotalia mexicana and gastropoda occur commonly. The faunal diversity is moderate and bulk of faunal number is represented by larger foraminifera as shown in the gross foraminiferal assembalge. Many genera of benthic foraminifera replace the nummulitidae in the Austrotrillina howchini, overlying shaly sediments. Cibicides lobatus, Acostina and many species of nodosaridae and miliolids are present frequently.

Sharp reduction in foraminiferal appearance is noted in the overlying sediments. The fauna is not matrix free and of worn out type. Occurrence of bryozoa and ostracoda Cytheretta is noteworthy.

<u>Nummulites</u> once again dominate the fossil content in the overlying sequence. <u>Nummulites fichteli</u>, <u>N.</u> <u>intermedius</u> occur together with <u>Lepidocyclina Eulepidina</u> <u>dilatala</u> and <u>Operculina</u>. Larger foraminiferal shells are pinkish white coloured and very fragile. Many genera of benthic foraminifera are present further



FIG. 4-1, BIOSTRATIGRAPHY OF RATIPAL SECTION:

upwards alongwith delicate oyster shells. Both faunal number and diversity is high. In the overlying thick, massive coralline limestone, fauna adheres to the carbonate mud matrix. Thin section study reveals, besides corals, presence of <u>Sphaerogypsina globulus</u> Ruess and <u>Pyrgo bulloides</u>. The faunal number is high but diversity is low.

Only few smooth shelled ostracoda belonging to genera <u>Haplocytheredea</u> and bryozoa are recovered from the overlying red siltstone band. Flattened large sized echinoids and gastropoda are present. This marks the top of Ramania stage.

The total absence of reticulate <u>Nummulites</u> from the samples overlying siltstone sequence is striking. Larger foraminiferal assemblage comprises of <u>Operculina</u> spp. <u>Lepidocyclina</u> <u>Eulepidina</u> <u>dilatata</u>, <u>L.E</u> <u>premarginata</u>, <u>L. Nephrolepidina</u> <u>nipponica</u> and <u>Miogypsina</u> (<u>Miogypsinoides</u>). Besides, miliolids and <u>Planolinderina</u> <u>freudenthali</u> are common. High benthic foraminiferal number and diversity is noted from the overlying shales, <u>Anomallinella</u> <u>rostata</u>, <u>Cibicides</u> <u>pseudoungeriana</u>, <u>Acostina</u> <u>piramidale</u>, <u>Bolivina</u> <u>marginata</u>, <u>Rectobolivina</u>, <u>Nodosaria</u> <u>regularis</u>, <u>Globoratalia</u> <u>opima</u>, <u>Globigerina</u> sp, Rotalia are recovered (Tewari et. al. 1968).

Very high number and very low diversity characterise the <u>Spiroclypeus</u> rich silty dolomite, towards the top of Ratipal section. Only few juvenile benthics together with gastropods and bryozoa occur in the red siltstone band which mark the top of Waior stage.

Contraction of the local division of the loc		CONTRACTOR INCOME				the state of the s	-
AGE	SERIES	STAGE	FORAMINIFERAL ZONES	LITHO- LOGY /	CHARACTERISTIC FAUNA	INFERRED PALEO- BATHYMETRY	TR/RG CYCLES
ш			ABUNDANT SPIRO-		Illpreserved benthics	Marginal to nonmarine	
A ET		с О	NAE PARTIAL RANGE ZONE		Spiroclypeus ranjanae, Operculina	lnner shelf Bathy 10–15m	RG 3
z	-	A	ANOMALINELLA ROSTATA GLOBIGE- RINA SPP. ASS. ZONE		Nodosaria, Globigerina Praebulloides,Globorotalia opima	Inner shelf Bathy. 30-40m	
ц Ш	۲	3	M. (MIOGYPSINOIDES cf. BERMUDEZI- PLANOLINDERINA	-/- [Rotalid s	Inner shelf Bathy < 20m.	TR3
U	0		ASS. ZONE		Reworked fauna	Littoral to nonmarine	RG2
L 0 Y	×	ح «	NUMMULITIES FICH TELI L. EULEPI- DINA DILATATA ASS. ZONE		Coral, Sphaerogypsina, Pyrgo	Well oxygenated, normal marine, clear,warm waters Bathy 15-20m.	TR 2
о ч –	с ш	z a		7 - 7 7 - 7 - 7 - 7	Reti. Nummu. L epidocy - clina Eulepidina ,R otalia	Inner shelf , Bathy < 20 m.	
Д		Σ		-, 1-	Broken fauna	Marginal lagoonal to	X RGI
 	80	⊥ ≺ 0	BOLIVINA-CIBICIDES	I	Bolivina , Cibicides Plankton	littoral Inner shelf, Bathy. 20-30m	· *
0		۲ ۲ ۲	RECTICULATE NU- MMULITES ACME	<u>]</u>]	Coral,S phaerogypsina, P yrgo	Clear, warm water, Bathy, < 20 m.	TRI
		R	ZONE	 	Reti. Nummu. Pararotalia Juyenile benthics	Shallow marine Bathy, 15 — 20m.	
LEG	ARGI		S D OLOMITE SILTST	ONE/WITH	CALCAREOUS SILT STONE	SCALE : $\begin{bmatrix} 5' \\ 0 \end{bmatrix}$	
		DOLOMI	TE SHALE	AREN	LIME STONE WIT		
FI	G.Z	4·3, F F F	PALEOBATH REGRESSIV PARAMETEI	IYMET E CY RS, R	RY AND TR CLES BASED ATIPAL SECT	ANSGRESS ON FAUN ION	IVE / A L

Detailed vertical faunal distribution of the Ratipal section is displayed in Figure 4.2

Paleobathymetry and transgressive cycles

Figure 4.3 shows the bathymetry of depositing medium at the time of Bermoti series of Ratipal section. At the time of deposition of <u>Anomalinella rostata-Globigerina</u> spp. assemblage zone, basin attained maximum bathymetry of 30 to 40 metres. Total three sedimentry cycles are noticed, during the deposition of Bermoti series of this section. Lower Ramania, upper Ramania and Waior sediments were deposited in one cycle each. Microfacies data, however, indicates two sea level fluctuations during both lower and upper Ramania times.

4.2.2 Bermoti Section

A good number of miliolids, ill-developed boliviniids together with Elphidium, Florilus, Pararoralia, ostracoda Cytheretta and bryozoa occur in the siltstone sequence at the base of Ramania stage of Bermoti section (Figure 4.4). Patchy corals found above this are associated with Sphaerogypsina globulus and Pyrgo bulloides. The intervening limestone sequence is studded with Nummulites N: fichteli, N intermedius, N. clipeus, and Pararotalia mexicana make up the faunal assemblage. Overlying thin sequence of greyish green coloured shale is poorly fossiliferous. Reticulate Nummulites assemblage occurs above the shale, which in turn is followed by calcareous sandstone band with very sparse fauna, constitutting few gastropods and echinoids.



FIG. 4.4, BIOSTRATIGRAPHY OF BER-MOTI SECTION.

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as nodasariids, boliviniids, Deep-dwelling benthics such buliminids, cibicides are associated with Austrotrillina and other miliolids. Few Globorotalia and Globigerina specimens are also present in the cement coloured shale. Both benthic faunal number and diversity is high. Towards the top, but for ostracoda Cytheretta and bryozoa, drastic reduction of faunal content is noticed. This is followed by massive limestone sequence comprising coral, algae and molluscan shell. Sphaerogypsina globulus and Pyrgo bulloides are the only foraminifera present. Lepidocyclina Eulepidina dilatata, L.(E.) formosa, Nummulites fichteli, N. intermedius constitute the bulk of larger foraminiferal assemblage of limestone in upper Ramania stage Above this, calcareous siltstone band of the Bermoti -section. contains broken faunal tests with boring holes, Ostracoda Hyplocytheridea, Cytheretta and bryozoa mark top of Ramania strata.

<u>Miogypsina</u> <u>Miogypsinoides</u> cf. <u>bermudezi</u>, <u>Lepidocyclina</u> <u>Eulepidina formosa</u>, <u>L. Nephrolepidina</u>, <u>Operculina</u> and <u>Planolinderina</u> <u>frudenthali</u> occur in basal part of Waior stage. <u>Anomalinella rostata</u>, <u>Nodosaria</u>, <u>Bolivina</u>, <u>Bulimina</u>, <u>Brizalina</u>, <u>Acostina</u>, <u>Globorotalia</u> <u>opima</u> <u>nana</u>, <u>Globigerina</u>, ornamented ostracoda <u>Actinocythereis kutchensis</u> are the associated taxa, (Khosla et. al. (1981).

Faunal assemblage constituting coral, <u>Sphaerogypsina</u>, <u>Pyrgo</u> and algae occur above and is followed by <u>Spiroclypeus ranjanae</u> in the argillaceous dolomite sequence. Towards the top of Waior stage, red coloured marl band contains only few broken, ill preserved fauna and clay pellets. Figure 4.5 illustrates detailed vertical faunal destribution in Bermoti sequence.

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Paleobathymetry and transgressive regressive cycles.

Lower Ramania sequence is marked by oscillating sea as indicated by three short lived transgressions and regressions. The bathymetry ranged between 5 to 30 metres (Figure 4.6). Upper Ramania and Waior depositions are the outcome of one transgressiveregressive cycle each, suggesting stable basinal conditions. Maximum bathymetry of 35-40 metres was attained during transgression TR5, resulting in deposition of shale in middle part of Waior stage. Inference drawn on sedimentary cycles are similar for lower and upper Ramaina stage, on the basis of both, faunal and microfacies. However, latter shows presence of two sedimentary cycles during Waior stage deposition.

4.2.3. Bernani Section

As in other sections, presence of minute boliviniids and miliolids, together with brown/olive green pellets, mark the base of Ramania stage of this section, (Figure 4.7).

A good number of reticulate <u>Nummulites</u>, <u>Heterostegina</u>, <u>Operculina</u> and <u>Rotalia</u> occur in <u>underlying</u> sequence, which in turn is overlain by poorly fossiliferous calcareous marl.

Abundant reticulate <u>Nummulites</u> reappear together with <u>Heterostegina</u> kohili, <u>Operculina</u> vinotti, <u>Pararotolia</u>, <u>Florilus</u> and ostracoda Actinocythereis ramaniaensis and <u>Leguminocythereis</u>.



FIG. 4.7 BIOSTRATIGRAPHY OF BER-NANI SECTION.

A sudden and drastic reduction of foraminifera is observed at the top of lower Ramania stage. <u>Haplocytheridae</u> and few <u>Cytheretta</u> are the only ostracoda present. The size of ostracoda matches with that of oval shaped glauconitic pellets. In the overlying shalysequence high faunal number and diversity is observed, <u>Nodosaria</u>, miliolids, <u>Austrotrillina</u>, <u>Cibicides</u>, <u>Bolivina</u>, <u>Discorbis</u>, <u>Pararotalia</u>, <u>Planolinderina</u>, <u>Gypsina</u> and <u>Florilus</u> are the main benthics present. The sequence is also noted for the diverse ostracoda content such as <u>Actinocythereis</u> <u>ramaniensis</u>, <u>Stigmatocythere</u>, <u>Hemecythere</u> and <u>Dentokrithe</u>.

In the intervening limestone sequence <u>Nummulites</u> are well developed. Generally, larger foram tests are thin, disc shaped, fragile and are arranged parallel-sub-parallel to each other. Overlying calcareous sandstone is poorly fossiliferous.

In the upper Ramania stage limestone, big, robust and microspheric forms of <u>Nummulites</u> are developed. Besides, occurrence of <u>Lepidocyclina Eulepidina dilatata</u> is noted. Among the associated taxa, specimens of <u>Rotalia</u> are frequent, followed by miliolids and <u>Planorbulina</u>. Coralline limestone occur above the <u>Nummulites</u> dominated sequence in which big, round species of <u>Sphaerogypsina</u> <u>globulus</u> and miliolids mainly <u>Pyrgo</u> are present. Occurrence of ostracoda <u>Hyplocytheredae</u>, bryozoa and reworked fauna mark the top of Ramania stage.

The thin section study of dolomitic limestone of Waior stage

T				an a				,
AGE	SERIES	STAGE		FOR AMINIFERAL ZONES	LITHO- LOGY	CHARACTERISTIC FAUNA	INFERRED PALEO- BATHYMTERY	TR/RG CYCLES
		۵		ABUNDANT SPIRO-	·····	Very sparsely fossili- ferous	Marginal marine to nonmarine	
		0		CLYPEUS RANJANAE PARTIAL RANGE	-1-	Spiroclyp eus ranjanae	Shallow marine	RG6
F		-		ZONE		Operculina	Bathy. 8-10m	
A		A		ANOMALINELLA ROS- TATA GLOBIGERINA SPP. ASS. ZONE		Bolivina ,B rizalina ,Globige rina, Globorotalia	Inner shelf 20-25m. deep	×
	-			M. (MIOGYPSINOIDES		Coral Sphaerogypsina Pyrgo	Warm waters 10-15 m.	TRe
_		≥		¢f. BERMUDEZI — PLANOLINDERINA ASS. ZONE		Bolivina, milioids	Inner shelf Bathy. 20-25m.	
	F		U		HI I	Echinoids	Marginal marine to nonmarine	RG
	0		P	NUMMULITES FICH-		Reti. Nummu., L.eulepidina Rotalia	Shallow marine Bathy, 10 - 15 m.	
			E	INA DILATATA	•	Weathered fauna	Marginal marine	RG,
~	Σ	Д	R	ASS ZONE		CoralSphaerogypsina Pyrgo	Warm, clear waters Bathy, 15-20 m.	
		-	_			Reti. Nummu. L .E u le pidina	Shallow marine Bathy, 10-15m.	
	~		L			Poorly fossiliferous	Shallowing	RG3
	ŭ	z		BOLIVINA-CIBICIDES		Bolivina Cibicid es	Inner shelf 20-25 m. deep	TR3
œ			0	ASS. ZONE		Poorly fossiliferous Boliving Cibicides	Oscillaling sea	RG X RG
	ш	Д	U		1-1-	CoralSphaerogypsina Pyrgo	Clear, open sea up to 15–20m. deep	TR,
A		Σ	W			Reti, Nummu.Rotalia	Shallow marine, Bathy, 15-20m.	
	ш		E			Ostracoda, Bryozoa	Local shallowing	RG X RG
ш		A	-	RECTICULATE NUMM		Reti. Nummu, Helero- stegina	Shallow marine Bathy,15–20m.	TR ₂
			R	ZONE	11	Ostrocoda, Bryozoa	Ocillaling sea,shallow than 5m.	RG
					HH	Reti, Nummu, Operculi na, R otalia	Shallow marine Bathy, 15-20 m.	
E	LIME	STON	E/	WITH GLAUCONITE	ARGI	LA.DOLOMITE DOLOM	IITE SCA	LE: 5
	SILT	STONE /	/ W	SHALE	LIMES	TONE / WITH MINOR CA	ALC. GLAUCONITIC S	ILTY
-10	5.4	.9,1		ALEOBATH EGRESSIVE	YMET E CYC	RY AND TRA	NSGRESSIN	/E / AL

shows good coralline growth and occurrence of Sphaerogypsina and In the overlying carbonate sequence Miogypsina Miogysinoides Pyrgo. and benthics particularly miliolids viz Quinqueloculina, Sigmoidina, Austrotrillina and Pyrgo are common. Among ostracoda Bairdia, Hermanites are noted. Lepidocyclina Nephrolepidina, Planolinderina occur commonly in the lower part, Anomalinella rostata, Cibicides, Nodosaria, Acostina are the faunal constituents occuring in the middle part of Waior stage. Towards the top, abundant big forms of Spiroclypeus ranjanae are arranged paralled to each other. Here the faunal diversity is low while number is very high. Overlying red siltstone band is very poorly fossiliferous. Figure 4.8 shows detailed vertical distribution of fauna occurring in Bernani section.

Paleobathymetry and transgressive regressive cycles.

Three transgressive-regressive cycles in lower Ramania and two cycles in upper Ramania are observed, suggesting unstable conditions during Ramania deposition of Bernani section (Figure 4.9). During Waior Sedimentation, maximum depth of sea was of the order of 25 to 30 metres and deposits were accumulated in one sedimentary cycle. This is in accordance with the conclusion drawn on microfacies study. However, latter shows one cycle for upper Ramania stage and two for lower Ramania stage deposits.

4.2.4 Waior Section

Few bryozoa and mollusc shells are recovered from the glauconitic silfstone occurring at the base of Ramania stage (Figure 4.10). In the overlying sediments miliolids and dwarf



FIG. 4-10 BIOSTRATIGRAPHY OF WAIOR SECTION.

boliviniids make their presence. Abundant <u>Nummulites fichteli</u>, and <u>N</u>. <u>intermedius</u> characterise the overlying sequence. <u>Heterostegina</u>, <u>Operculina</u>, <u>Planorbulina</u>, <u>Grzybowskia</u>, <u>Pararotalia</u> and <u>Nonion</u> comprise associated taxa. However, no identifiable fauna other than bryozoa is observed in the overlying yellow ochreous shaly band.

Plenty of delicate tests of reticulate <u>Nummulites</u> are arranged parallel to each other in the overlying silty limestone. Besides <u>Rotalia</u>, <u>Pararatalia</u>, and few specimens of <u>Hermanites</u> ostracoda comprise faunal assemblage which is high in number but moderate to low in diversity. Benthic foraminifera viz. <u>Cibicides</u>, <u>Austrotrillina</u>, <u>Nodosaria</u>, <u>Bolivina</u>, miliolids, <u>Rotalia</u> and ostracoda belonging to the genera <u>Leguminocythereis</u>, <u>Stigmatocythere</u>, <u>Pokornyella</u>, and <u>Actinocythereis</u> <u>ramaniaensis</u> constitute the faunal assemblage of siltstone band. In the overlying sequence, heart shaped echinoids, bryozoa and ostracoda Cytheretta are present.

<u>Lepidocyclina</u> <u>Eulepidina</u> <u>dilatala</u> together with reticulate <u>Nummulites</u> appear in the overlying thick carbonate sequence. <u>Miliolids</u> and Rotalia are associated benthonic foraminifera.

Robust microspheric forms of larger foraminifera dominate the faunal assemblage. <u>Nummulites</u> limestone grades upwards into massive coral-algal. limestone in which <u>Sphaerogypsina</u> globulus and <u>Pyrgo bulloides</u> are associated taxa. For both the limestones faunal number is very high while diversity is low. <u>Grzybowskia</u>, <u>Archias</u> and <u>Heterostegina</u> occur intermittantly. The top of Ramania stage is

characterised by glauconite pellets, ostracoda <u>Cytheretta</u>, <u>Haplocytheridea</u>, bryozoa, flattened echinoids and gastropods. <u>Planolinderina frudenthali</u>, <u>Miogypsina Miogypsinoides</u>, cf. <u>bermudezi</u>, miliolids, ornamented ostracoda <u>Actinocythereis kutchensis</u> form the rich faunal constitutent of lower part of Waior stage. Miliolids include Austrotrillina, Quinqueloculina and Pyrgo spp.

High foraminiferal number and diversity is observed in the overlying sediments which constitute Anomalinella, Rotalia, Cibicides, Eponids, Bolivina, Lepidocyclina Nephrolepidina, Borelis, Miogypsina (Miogypsinoides) complanata and ostracoda Actinocythereis kutchensis, $\underline{A} \cdot \underline{spinellosa}$, Pokornyella, and Stigmatocythere. This rich and diverse fauna dwindles upwards, and is characterised by plenty of mollusc shells and ichnofossils. Reddish brown calcareous siltstone band is full of <u>Spiroclypeus</u> ranjanae and few <u>Operculina</u> Unfossiliferous sequence with clay pellets marks the top of Waior stage. Figure 4.11 displays vertical faunal distribution in detail.

Paleobathymetry and transgressive regressive cycles -

Compared with the regressive phases of lower Ramania times, as observed in other sections, regressions RG1 and RG2 (lower Ramania stage) of Waior section, are of longer duration (Figure 4.12). Total six sedimentary cycles are responsible for Bermoti series depositon; of which 2 cycles are responsible for lower Ramania

-		the second second second					
AGE	SERIES	STAGE	FORAMINIFERAL ZONES	LITHOLO- GY	CHARACTERISTIC FAUNA	INFERRED PALEO- BATHYMETRY	TR/RG CYCLES
			ABUNDANT SPIRO-	=:=:=:=	Rare benthics, clay pellets	Littoral	RG6
ш ^Ш		0	CLYPEUS RANJANAE PARTIAL RANGE ZONE		Spiroclypeus ranjanae	Shallow marine Bathy, 10-15m.	TR 6
			ANOMALINELLA RO-		Bryozoa	Marginal marine	RG.5
-		-	STATA-GLOBIGERINA SPP. ASS. ZONE	1-1	Nadosaria		×
4	-	A			Bolivina — Miliolids planktons	Bathy, around 30m.	TR.5
ш	⊢		M. (MIOGYPSINOIDES)	E E E	Reworked fauna	Shallowing	RG.4
		5	PLANOLINDERINA ASS. ZONĘ	· _ · [· _ ·]	Bolivina, Miliolids	Shallow marin e Bathy. 20-25m.	TR.4
U	0				Pellets, reworked fauna	Littoral to Non— marine	RG. 3
> 0	5	∢ U	TELI L.EULEPI- DINA DILATATA ASS. ZONE		Coral – Sphaerogypsina — Pyrgo	Inner shelf, marine water Bathy. ≺ 20 m.	
с г С	œ	P P E Z R			Nummulites fichteli — Lepidocyclina — Eulepi- dina dilatata	Inner shelf Bathy, 10-15m	TR.3
α		A		I	Reti. Numm. – Pararotalia	Shallow marine	RG.2
-		L	BOLIVINA-CIBICID-		Grzybowskia, Helerostegina	Shallow marine	
⊲		Σ ()	LO ASS. ZONE		Poorly fossiliferous	Shallowing of sea	
	œ	W			Bolivina, Miliolids	Bathy, < 5m.	RG.I
ш		⊄ E R	RECTICULATE NU-	/-/	Poorly fossiliferous Reti. Nummulites, Operculina	Shallow marine	TR.I
		œ	ZONE	±	Bryozoa, MolluscaOstra Hyplocytheredae	toLittoral	
150	ENO				Broken benthics, glauconite pellets	Bamy, 0-5m	· · · · · · · · · · · · · · · · · · ·
LEC	EnU	LIME STO	DNE SHALE			SCALE :	
	ARE	ACEOUS	LIME STONE		DOLOMITE	LO	
		=:=:=:=:				5-	
	SILT	STONE / V	WITH GLAUCONITE	SILT	Y LIMESTONE ARGI	LLA. DOLOMITE	
FI	G. /	412 F	PALEOBATH	IYME.	TRY AND TRA	ANSGRESS	IVE /
				E CV	CIEC DACED	ON EALIN	

REGRESSIVE CYCLES BASED ON FAUNAL PARAMETERS, WAIOR SECTION. deposits, one cycle for the upper Ramania sediments and 3 cycle for the Waior sequence. However, microfacies data shows 2 cycles for upper Ramania stage thus making the total cycles as seven. Oscillatory marine conditions prevailed in lower Ramania and Waior deposition while upper Ramania deposition took place in comparatively stable environment. The maximum water depth of 25-30 metres is observed in the middle part of Waior stage.

4.3 AGE AND BIOZONES

4.3.1 Foraminiferal Makers of Bermoti Series

Detailed biostratigraphic discussion of sections have led to identify age diagnostic micropaleontological markers of Bermoti series. Ray (1985), similarly has worked out age and taxonomical relationship for the Cretaceous deposits in the Algarve, Southern Portugal. Table 4.1 shows observed ranges of biostratigraphically significant taxa of Bermoti series. Reticulate Nummulites viz. Ν. fichteli and N. intermedius range from base to the top of Ramania stage, while Lepidocyclina Eulepidina dilatata appears in the upper Ramania stage and continues in Waior stage. Austrotrillina howchini is another marker of Ramania stage.

Foraminiferal markers of Waior stage include <u>Miogypsina</u> <u>Miogypsinoides</u> cf. <u>bermudezi</u>, <u>Planolinderina</u> <u>frudenthali</u>, <u>Lepidocyclina</u> <u>Nephrolepidina</u>, <u>Spiroclypeus</u> <u>ranjanae</u>, <u>Anomalinella</u> <u>rostata</u> and planktonic foraminifera Globorotalia opima.



4.3.2 Age

Many workers have described the foraminiferal contents of Bermoti series (Raju 1973, Samanta 1970, Pandey 1982). According to them early Oligocene Ramania stage is taken as equivalent to planktonic foraminiferal zones P-18 and P 19 and late Oligocene age Waior stage includes plankton foram zones P 20 /N1, P 21/N2, P23/N3 and N4 (part).

Owing to their wide distribution and fast phylogenetic evolution, planktonic foraminifera is widely used for zonation. Table 4.2 shows standard planktonic foraminiferal zones proposed by Bollie and Saunders (1985). However, in shallow water deposits, especially carbonates, planktonic foraminifera occur only in small numbers or are absent (Luterbatuer 1984, Mcgrowan, 1985). van der Vlerk and Umbgrove (1927), have proposed a "Letter stage classification of .Tertiary" based on larger foraminifera which 'occur abundantly in carbonates. It was revised and applied to the entire Indo – west-Pacific region by Adams (1970, 84 and 85). Table 4.3 summarises the history of Letter stage zone.

Adams, (1984) in the Oligocene Letter stage zones has recognised three successive assemblages of larger foraminifera (Table 4.4). The oldest defined as Tc is characterised by the presence of <u>Nummulites</u> without <u>Lepidocyclina</u>, second oldest, Td, includes <u>Nummulites</u> and <u>Lepidocyclina</u> while youngest. Te 1-4 contains <u>Lepidocyclina</u> without <u>Nummulites</u>. Adams, (1984, op.cit), has equated Letter stage boundaries with those of planktonic foraminiferal

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(AFTER ADAMS, 1984) TABLE 4.3, HISTORY OF FAR EAST LETTER STAGE ZONES DEVELOPMENT.

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GER FORAMINIFERAL EVENTS OF OLIGOCENE EPOCH FAD : FIRST APPEARANCE DATUM; LOD:LAST OCCURRENCE DATUM.	: <u>Miogypsina borneensis</u> - <u>M</u> . <u>tani</u> : <u>Heterostegina borneensis</u> group <u>Spiroclypeus</u>	Miogypsina gunteri	: Miogypsinoides complanatus group	: Nummulites fitchelli group	: <u>Austrotrillina howchini</u> group	Nummulites vascus group Genus Lepidocyclina (Eulepidina) group	Discocyclinidae - Pellatispira, Fabianina, Biplanispira and <u>Alveolina</u> .
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LETTER LETTER FAGES OF FAGE EAST	Upper Te (=Te 5 Part)	(=Те−1-4) ∟омег Те			рΤ	ът	Tb (Part)
STANDARD PLANKTONIC FORAMINIFERAL ZONES	Globigerinoides primordius	Turborotalia kugleri Globigerina ciperoensis	Turborotalia opima		Globigerina ampliapertura	Cassigerinella chipolensis Pseudohastinge- rina micra	Turborotalia cerroazulensis s.l.
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TABLE:4.4 LARGER FORAMINIFERAL EVENTS OF OLIGOCENE

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Time (m.y)	Sub-era	Epochs	Stage	P&N Zones	Letter Stage			F	lang	es c	of cr	itica	il tax	(0		
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		<u>o</u>	PIACENZIAN	N19-N21	Tg											
5			ZANCLIAN													
5			MESSINIAN	N 17												
10			TORTONIAN	N16	Tf3									(snad)		
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zones (Table 4.5). He has also shown the ranges of critical taxa used for zonation.

The comparison of observed ranges of significant taxa of Bermoti series (Table 4.1) with the established ranges of larger foraminifera (Table 4.5) gives a good lead to tie the Ramania and Waior stages with standard Letter stage boundaries. Age disgnostic larger foraminiferalmarkers present in the present study are reticulate Nummulites, Lepidocyclina Eulepidina, L.Nephrolepidina. Μ. Miogypsinoides and Spiroclypeus. In lower Ramania stage, reticalate Nummulites dominate the faunal assemblage. Co-occurrence of Lepidocyclina Eulepidina and Nummulites is noted in upper Ramania stage. The generated data is compared with the works of kepkemeti, (1981) and Cavelier et. al. 1981 regarding Eocene/Oligocene boundary Thus, the first appearance datum of L. Eulepidina divides, events. the lower and upper Ramania as equivalent to Tc and Td respectively and last occurrence datum of Nummulites fichteli marks the boundary between Ramania and Waior stages. Larger foram markers, further enable to equate the Ramania stage with European chronostratigraphic stage Rupelian and the Waior with the Chattain. In terms of geological ages, the Ramania stage corresponds to 36.6 Ma to 30 Ma.

As mentioned above, first appearrance datum of <u>Miogypsina</u> in Waior felicitates to tie it with letter stage lower Te 1-4, (Raju 74). Additionally, presence of <u>L. Nephrolepidina</u>, <u>Planolinderina</u> <u>frundenthali</u> in the lower part, <u>Anomallinella rostata</u> in the shaly middle part and <u>Spiroclypeus ranjanae</u> in the upper part of Waior stage helps to equate it with Adam's (op. cit.) Letter stage, lower Te, ie Te 1-4. The occurrence of planktonic foraminiferal marker, <u>Globorotalia</u> <u>opima</u> (P21/N2) afirms the age determination. (Keller, 1983). Waior stage is, thus, equivalent to Chattian stage ranging between 30 and 23.7 millions years.

4.3.3 Biozones

Biozones proposed by Raju (1974) for the Bermoti series has taken as initial base and the present work is further detailed and high resolution refinement.

In the lower Ramania, two distinct biozones occur, viz. Reliculate <u>Nummulities</u> Acme Zone in lower part and <u>Bolivina-Cibicides</u> Assemblage Zone in upper part. Upper Ramania comprises of <u>Nummulites fichteli</u> - <u>Lepidocyclina Eulepidina dilatata</u> Assemblage Zone.

Within Waior stage three biozones are recognised. They are <u>Miogypsina</u> (<u>Miogypsinoides</u>) cf. <u>bermudezi</u> - <u>Planolinderina</u> <u>fraundenthali</u> Assemblage zone, <u>Anomalinella Rostata</u> - <u>Globigering</u> spp. Assemblage Zone and <u>Spiroclypeus</u> <u>ranjanae</u> Partial Range Zone from base to top. Thus, the biostratigraphy of Bermoti series is evolved with six biozones of which three biozones are recognised in Ramania stage. Waior stage, similarly, is divisible into three biozones. All of them can be marked in Ratipal, Bermoti, Bernani and Waior sections and are fairly correlatable, (Figure 4.13).

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	NODOSARIA – AUSTROTRILLINA BIOFACIES
	NUMMULITES-HETEROSTEGINA -PARAROTALIA BIOFACIES
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	CORAL- SPHAEROGYPSINA-
	PYRGO BIOFACIES
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