CHAPTER-8

PALYNOSTRATIGRAPHY

8.1 INTRODUCTION

Palynological fossils are valuable tools that are used to precisely solve the various types of geological problems in continental as well as nearshore deposits. Because of their association with fuel-bearing deposits, well preservations and their abundance with minimal morphological changes gained the utmost significance in the local and regional correlation purpose throughout the Phanerozoic Era and even between the continental and marine nearshore deposits. Their fine nature makes them easily strewn and transported by wind and water, chances of availability of these types of fossils are immense in the fine-grained rocks attracting palynologists. These fossils have enhanced knowledge of palynoflora and utility in their correlation purpose as well as paleoenvironment, paleoecology, paleoclimate, and paleogeography. In the modern day, palynostratigraphic importance is more vital because it deals with the timing of vegetational successions based on the identification of pollen and spore assemblages in their stratigraphic context including lithostratigraphy (Zobaa, 2009; Mehrotra et al., 2012; Bercovici and Vellekoop, 2017).

The age slot of the investigated area is a concern, valuable economically viable lignite deposits are occur in different parts of India, and their marine parts are rich in hydrocarbon deposits. Particularly, concerning Gujarat state, many active open cast mines are exploiting the lignite in the Bharuch, and Surat districts of the South Gujarat, Bhavnagar districts of the Saurashtra region and Kachchh district. Their associated sedimentary horizons are worked by many workers (Kar and Bhattacharya, 1990; Tripathi et al., 2000; Singh et al., 2012, 2015, 2017) on palynological aspects and compare the vegetation gradient of the Paleogene. Attempts have also been made for Palynostratigraphy (Tripathi and Srivastava, 2012; Monga et al., 2015; Sharma and Saraswati, 2015) and successively divisible into the number of biozones.

In the present investigation, the area falls in the Saurashtra region, whereby deposits occurred as intra, intertrappean bearing equivalent time space with lignite deposits, but the absence of the lignite in this region makes them different in paleoenvironment is a concern. The investigator has analysed the palynological elements from the Ninama and Chotila

Intertrappeans of the Saurashtra Peninsula and has provided insights into the palynofossils type, paleovegetation, and succession during their deposition. These two areas comprise a smaller number of the palynofossils in their early deposits, but diversity and abundance increase in the upward direction. They comprise the important palynofossils, opisthokonts, phytoclasts, freshwater algae belonging to Chlorophyceae, various phytoplanktons, dinoflagellates, amoeba, fungal fruiting bodies, fungal spores, pteridophytes, and angiosperm pollens. The various palynofossils recorded from both the Ninama and Chotila Basin are listed in Table 8.1 and Table 8.2 respectively.

Palynofossil	Taxa
Pteridophyte spore and Pollen taxa	*Acanthotricolpites bulbospinosus*
	Aquilapollenites ovatus
	Arecipites bellus
	Araliaceoipollenites psilatus
	Araliaceoipollenites reticulatus
	Barringtoniapollenites retibaculata
	Crotonipollis densus
	Cupanieidites flaccidiformis
	Cupuliferoipollenites ovatus
	Cupuliferoipollenites psillus
	Cythidites australis
	Dermatobrevicolporites spp.
	Ephedripites sp.
	Hammenisporis susannae
	Lakiapollis ovatus
	Longaapertites triangulates
	Longapertites retipilatus
	Malvacearumpollis baconyensis
	Matanomadhiasulcites maximus
	Matanomadhiasulcites sp.
	Monocolpopollenites sp.
	Mulleripollis bolporensis
	Palmaepollenites communis

	Palmidites sp.
	Proxapertites cersus
	Proxapertites crassimurus
	Rhombipollis geniculatus
	Rhombipollis spp.
	Tricolporopollenites spp.
	Yeguapollis sp.
Fungal Remains	*Ceratohirudispora* sp.
	Frasnacritetrus indicus
	Fusiformisporites sp.
	Hypoxylonites subrotundus
	Inapertisporites kedvessi
	Inapertisporites maximus
	Monoporisporites circularis
	Palaeomycites acinus
	Palaeomycites spp.
	Papulosporites multicellatus
	Perisporiacites varians
	Polycellaesporites bellus
	Plureicellaesporites planus
	Udaria saxenae
Testate Amoeba	*Centropyxis aculata*
	Arcella arenaria
Dinoflagellates and Phytoplanktons	
Phytoclasts	
Chlorophyceae (*Botryococcus* sp. and *Pediastrum* sp.)	
Arthropod (Opisthokonta and Lepidopteran scales)	
Amorphous Organic Matter (AOM)	

Table 8.1 Generalized list of palynofossil groups observed from Ninama Intertrappeans. Note: They contain abundant Pteridophytes spore and pollen taxa, and fungal spores.

Palynofossil	**Taxa**
Pollen taxa	*Dermatobrevicolporites dermatus*
	Florschuetzia rajpardiensis
	Meliapollis ramanujamii
	Monocolpopollenites plicatus
	Proxapertites spp.
	Rhoipites kutchensis
	Tricolporopollenites sp.
Fungal Remains	*Dicellaesporites minutus*
	Diporisporonites sirmaurensis
	Frasnacritetrus indicus
	Frasnacritetrus tougourdeavi
	Helicomminites salvinites
	Hypoxylonites minimus
	Hypoxylonites sp.
	Inapertisporites kedvesii
	Inapertisporites maximus
	Inapertisporites novus
	Inapertisporites tetradus
	Meliolinites spinksii
	Palaeomycites acinus
	Palaeomycites spp.
	Papulosporonites multicellatus
	Perisporiacites varians
	Polycellaesporites planus
	Pluricellaesporites sp.
	Polycellaesporonites globatus
	Polycellaesporonites psilatus
	Polycellaesporites saxenae
	Protocolletotrichum deccansis
	Staphlosporonites setlyi
Testate Amoeba	*Centropyxis aculata*

	Arcella arenaria
Dinoflagellates and Phytoplanktons	
Phytoclasts	
Chlorophyceae (*Botryococcus* sp. and *Pediastrum* sp.)	
Arthropod (Opisthokonta and Lepidopteran scales)	
Amorphous Organic Matter (AOM)	

Table 8.2 Generalized list of palynofossil groups observed from Chotila Intertrappeans. Note: They contain abundant Pteridophytes spore and pollen taxa, and fungal spores.

Smith (1815) laid the foundation for biostratigraphy by being one of the first to recognize the value of fossils for dating rock layers. The contributions of Grabau (1913) and Simpson (1940) significantly broadened the scope and uses of biostratigraphy by highlighting the significance of index fossils. Brasier (1980) and Traverse (2007) used microfossils like foraminifera and pollen grains as key fossils to establish biostratigraphy (Brasier, 1980; Armstrong and Brasier, 2004; Traverse, 2007; Williams et al., 2018).

Biostratigraphic units serve as fundamentals in interpreting the temporal distribution of fossils within the geological sequences. The basic unit of biostratigraphy is called 'biozone' or 'biostratigraphic zone', which is a stratigraphic interval measured and characterized by selected aspects of its fossil content (Salvador, 1996).

There are five commonly used types of biozones: range zones, interval zones, assemblage zones, abundance zones, and lineage zones. Based on the selected attributes, a stratigraphic unit can be divided independently into biozones.

1. Range zone (Acrozone): A range zone represents a vertical stratigraphic interval where a particular fossil species or taxon, or two taxa is continuously present. It signifies the entire duration of the existence of a species within a stratum, aiding in the correlation of rock sequences (Salvador, 1996).
    a. Taxon-Range zone
    A taxon range zone represents a body of strata with total range of occurrence (horizontal and vertical) of specimens of a particular taxon (species, genus, family, etc.) (Salvador, 1996).
    b. Concurrent-Range zone

A concurrent range zone is represented by the concurrent or coinciding parts of range zones of two or more specific taxons, selected from the total taxons contained in the sequence of strata (Salvador, 1996).

c. Oppel zone

An oppel zone is represented by an association or aggregation of selected taxons, of restricted and largely concurrent range, chosen as indicative of approximate contemporaneity (Salvador, 1996).

d. Lineage zone (phylozone/evolutionary zone)

A lineage zone is represented by a body of strata containing specimens representing a segment of an evolutionary or developmental line or trend, defined above and below by changes in features of the line or trend (Salvador, 1996).

2. Interval zone: Interval zones are characterized by the occurrence of one or more specific taxa within a distinct stratigraphic interval. Unlike range zones, which cover the entirety of a species' occurrence, interval zones are shorter stratigraphic intervals marked by the presence of distinct taxa in a stratum between two specified horizons (Salvador, 1996). It is identified only based on bounding horizons.
3. Assemblage zone (Cenozone): An assemblage zone is defined by the co-occurrence of a specific group of fossils within a particular stratigraphic interval. These zones are characterised by the occurrence of three or more fossil taxa which differentiates it from the adjacent strata (Salvador, 1996).
4. Abundance zone: Abundance zones are determined by the relative abundance of a particular taxon within a stratigraphic sequence. These zones highlight intervals where a specific fossil taxon or group is notably abundant, aiding in detailed correlations and interpretations (Salvador, 1996).
5. Lineage zone: Lineage zones represent stratigraphic intervals that emphasize the evolutionary lineage or sequence of related taxa. They show the evolutionary progression or changes within a specific lineage across geological time, aiding in understanding evolutionary patterns (Salvador, 1996). It may represent the entire range of taxa within a lineage or only that part of the range of the taxon below the appearance of a descendant taxon.

In the present work, after detailed qualitative and quantitative palynological analysis, the investigator has observed that the lithological boundaries coincide with the palynological boundaries. The stratigraphic and ecologically significant palynotaxa were quantitatively assessed for delineation of the palynostratigraphic zonation. The presence or absence of palynotaxa is generally controlled by various environmental factors, distance from the source or habitat, and pollen productivity. The different palynozones (biozones) were marked considering the first or last appearances, the maximum abundance, the range in the vertical column, the restricted occurrences, and the decline of the palynofossils.

8.2 NINAMA BASIN

The Ninama Basin Intertrappean contains a diverse group of palynofossils. The lower part of the basin belonging to the Sukhbhadar Formation shows dominance of the fungal spores while the middle and upper part belonging to both, the Sukhbhadar Formation and Ninama Limestone are dominated by pteridophyte spores and angiosperm pollens. The temporal distribution pattern of palynotaxa recovered from individual samples in the vertical sedimentary succession of the Ninama Intertrappeans indicates four biozones (Fig. 8.1):

1. ***Palaeomycites* spp. Abundance Zone**

   Lithology: The vertical range of the biozone is limited to grey shale lithofacies of the Sukhbhadar Formation.

   Position: Sample 24-28, GSH lithofacies, Sukhbhadar Formation.

   Palynoassemblage: The palynozone is marked by significant dominance of *Palaeomycites spp.* (80%) in sample no. 25-28. The biozone also comprises of *Palaeomycites acinus, Udaria saxenae, Ceratohirudispora* sp., and rare occurrences of *Matanomadhiasulcites maximus* in descending order of abundance. The overall assemblage of the biozone is dominated by fungal spores with sparse occurrences of pollens.

   Upper limit: The appearance and gradual abundance of *Inapertisporites* spp. marks the upper limit of the biozone.

   Remarks: The overall palynoassemblage represents abundant Palaeomycites spp. with rare occurrences of amoebas and pollen taxa.

2. ***Inapertisporites* spp. Abundance Zone**

   Lithology: The vertical range of the biozone is limited to grey shale lithofacies of the upper Sukhbhadar Formation.

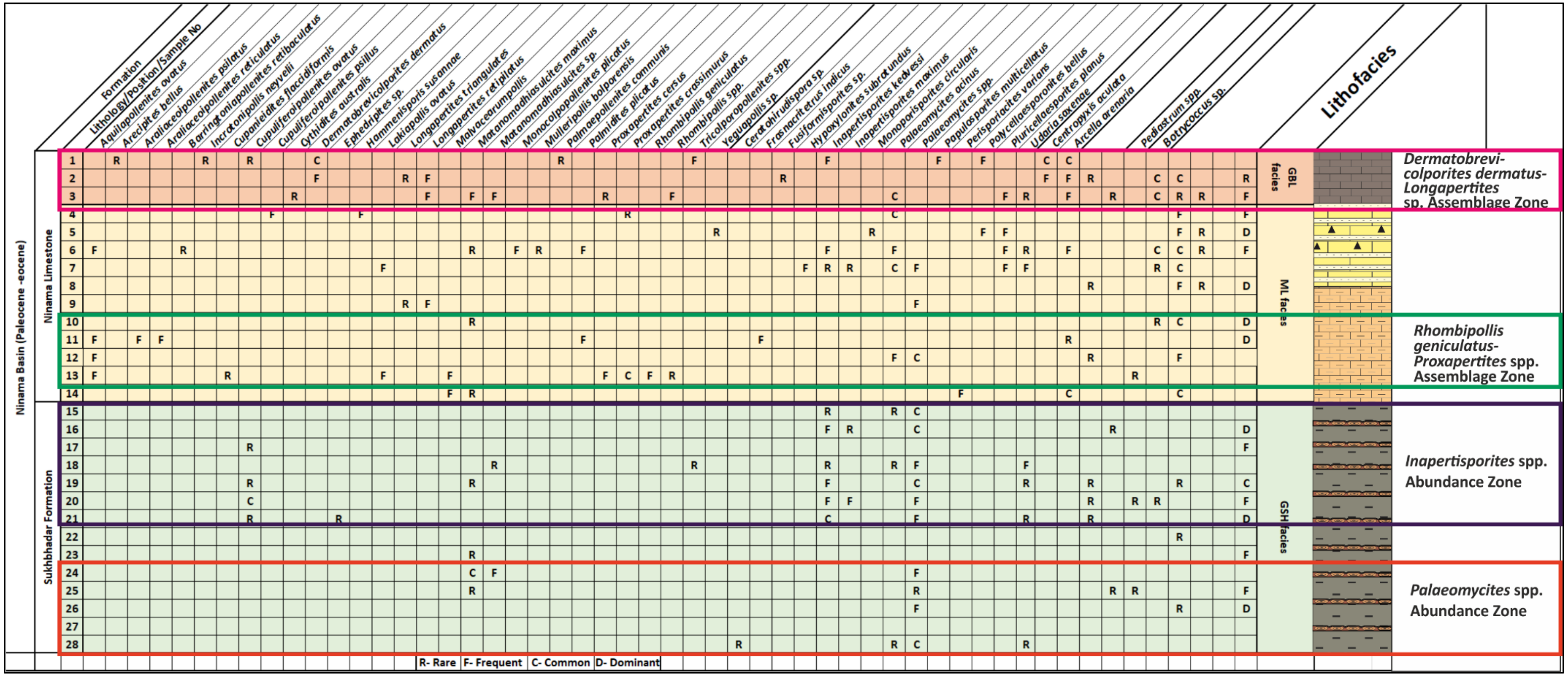

Fig. 8.1 Generalized litholog shows lithostratigraphy, lithofacies and systematic collection of the samples of the Ninama Intertrappeans. Palynofossils distribution shows their relative abundance in the systematically collected samples with their palynostratigraphic zonation. Ninama Limestone contains abundant and diverse palynofossils as compared to the lower Sukhbhadar Formation.

Position: Sample 15-21, GSH lithofacies, Sukhbhadar Formation.

Palynoassemblage: The palynozone is marked by significant dominance of *Inapertisporites* spp (60%) in samples 15-21. The biozone also contains *Cupuliferoipollenites ovatus, Ephedripites* sp., *Matanomadhiasulcites maximus*, *Tricolporopollenites* spp., *Inapertisporites kedvessi*, *Inapertisporites maximus*, *Palaeomycites acinus*, *Palaeomycites* spp. and *Arcella arenaria* in descending order of abundance. The overall assemblage of the biozone is dominated by fungal spores with sparse occurrences of pollens and testate amoebas.

Upper limit: The upper limit of the biozone is marked by the appearance of *Proxapertites* sp., *Rhombipollis* sp., *Lakiapollis* sp., and *Aquilapollenites* sp.

Lower limit: The lower limit of the biozone is marked by the appearance and abundance of *Inapertisporites* sp.

Remarks: The overall palynoassemblage is dominated by Inapertisporites and *Paleomycites* sp. i.e. fungal spores and elements.

3. ***Rhombipollis geniculatus* - *Proxapertites* spp. Assemblage Zone**

Lithology: The vertical range of the biozone is limited to marlite lithofacies of the Ninama Limestone.

Position: Sample 11-14, ML lithofacies, Ninama Limestone.

Palynoassemblage: The palynozone is marked by significant dominance of Proxapertites (50%) in sample no. 11-14. The biozone also comprises *Aquilapollenites ovatus, Areliaceoipollenites psilatus, Areliaceoipollenites reticulatus, Cupanieidites flaccidiformis, Lakiapollis ovatus, Proxapertites cersus, Proxapertites crassimurus, Rhombipollis geniculatus, Rhombipollis* spp*., Frasnacritetrus indicus, Palaeomycites acinus, Palaeomycites* spp*., Arcella arenaria* in descending order of abundance. The overall assemblage of the biozone is dominated by pollens, fungal spores, and testate amoeba.

Upper limit: The upper limit of the biozone is marked by the appearance and high frequency of pollen taxa like *Longapertites* sp. and *Dermatobrevicolpories dermatus*.

Lower limit: The lower limit of the biozone is marked by the appearance *of Proxapertities* sp*., Rhombipollis* sp*., Lakiapollis* sp*.*, and *Aquilapollenites* sp.

Remarks: The overall palynoassemblage of the biozone is dominated by pollen taxa belonging to palms.

4. ***Dermatobrevicolporites dermatus-Longapertites* sp. Assemblage Zone**

Lithology: The vertical range of the biozone is limited to grey-black limestone and cherty limestone lithofacies of the Ninama Limestone.

Position: Sample 1-10, GBL lithofacies, Ninama Limestone.

Palynoassemblage: The palynozone is marked by significant dominance of *Dermatobrevicolporites dermatus. and Longapertite* ssp. (50%) in sample numbers 1-4. The biozone also comprises of *Arecipites bellus, Crotonipollis densus, Cupuliferoipollenites ovatus, Cythidites australis, Dermatobrevicolporites* spp.*, Longaapertites triangulates, Longapertites retipilatus, Matanomadhiasulcites maximus, Matanomadhiasulcites* sp.*, Palmaepollenites communis, Proxapertites cersus, Rhombipollis* spp.*, Tricolporopollenites* spp.*, Inapertisporites kedvessi, Inapertisporites maximus, Papulosporites multicellatus, Plureicellaesporites bellus, Centropyxis aculata, Arcella arenaria* in descending order of abundance. The overall assemblage of the biozone is dominated by pollens and fungal spores.

Lower limit: The lower limit of the zone is marked by the appearance and increased frequency of *Longapertites* sp., *Dermatobrevicolporites dermatus,* and *Matanomadhiasulcites maximus*.

Remarks: The overall palynoassemblage of the biozone is dominated by pollen taxa belonging to palms with an increased testate amoeba.

8.3 NINAMA BASIN: AGE AND ENVIRONMENTAL IMPLICATIONS

The Ninama Basin is divided into four biozones stratigraphically, 1. *Palaeomycites* spp. Abundance Zone, 2. *Inapertisporites* spp. Abundance Zone, 3. *Rhombipollis geniculatus* - *Proxapertites* spp. Assemblage Zone, 4. *Dermatobrevicolporites dermatus* - *Longapertites* sp. Assemblage Zone (Fig. 8.1). The age and environment of each of these palynostraigraphic zones are discussed herewith coupling the data of the palynofossils, sedimentology, and geochemistry.

The lowermost zone, *Palaeomycites* spp. Abundance Zone is dominated by *Palaeomycites* spp., with rare occurrences of *Matanomadhiasulcites maximus*. Based on the presence and occurrence of *Matanomadhiasulcites maximus,* the age of the biozone is assigned, Paleocene (Samant and Mohabey, 2009; Saxena and Ranhotra, 2009). The dominance of fungal spores and mycorrhizae, and the near absence of pollens and pteridophyte spores suggest nonconducive and harsh conditions and less diversified vegetation (Kar and Saxena, 1974; El

Atfy et al., 2013). The low concentration of pteridophytic spores and pollens is also suggestive of probable intense volcanic activity in the surrounding area may have restricted the growth of vegetation during the deposition of the Intertrappean sediments.

The lowermost zone, *Palaeomycites* spp. Abundance Zone is followed by *Inapertisporites* spp. Abundance Zone. It is dominated by the occurrence of *Inapertisporites* spp. The zone is also characterized by fossil pollen like *Cupuliferoipollenites ovatus, Ephedripites* sp., *Matanomadhiasulcites maximus*, and *Tricolporopollenites* spp. Based on the presence of *Cupuliferoipollenites ovatus, Matanomadhiasulcites maximus* and *Tricolporopollenites,* a Paleocene-Eocene age (Kar, 1976; Samant and Mohabey, 2009; Saxena and Ranhotra, 2009; Wilde and Riegel, 2022) is assigned to the biozone. The dominance of fungal spores and mycorrhizae in the zone is also suggestive of a nonconductive environment, which probably continued. The dominance of fungal spores, the simplest life forms, and elemental ratios such as paleoredox and paleoclimate also suggest an anoxic condition and warm, humid tropical-subtropical climate (Kar and Saxena, 1974; Kar et al., 2010; El Atfy et al., 2013).

The *Inapertisporites* spp. Abundance Zone is followed by *Rhombipollis geniculatus - Proxapertites* spp. Assemblage Zone. The zone occurs in marlite lithofacies of Ninama Limestone and is characterised by the abundance of pollens like *Proxapertites* spp., *Rhombipollis geniculatus, Aquilapollenites ovatus, Areliaceoipollenites psilatus, Areliaceoipollenites reticulatus, Cupanieidites flaccidiformis, Lakiapollis ovatus, Proxapertites cersus,* and *Proxapertites crassimurus.* The presence of pollens like *Rhombipollis geniculatus, Aquilapollenites ovatus,* and *Lakiapollis ovatus*, suggests a Paleocene-Eocene age (Kar, 1985; Frederiksen, 1994; Samant and Mohabey, 2009; Saxena and Ranhotra, 2009; Samant et al., 2014; Monga et al., 2015). The palynoflora of the zone marks a characteristic rise in the pollens, suggesting that the new vegetation, that emerged, could exploit the extruded volcanic material and acclimate to the harsh environment. The zone also suggests intense chemical weathering in the surrounded area and tropical and subtropical climates, high rain precipitation based on Ti/Al and CIA-K ratios, megathermal trees, and possibly lowland shrubby forests in the nearby areas of the lake have been developed. The presence of *Botrycoccuss* sp. also indicates the prevalence of alkaline conditions in the water (Limaye et al., 2007; El Atfy et al., 2013; Kumar et al., 2016). During the time of deposition, the abundance of fungal remnants, in the zone, also marks a humid tropical climate and a closed freshwater environment.

The uppermost biozone identified in the Ninama Basin is *Dermatobrevicolporites dermatus - Longapertites* sp. Assemblage Zone. The zone is rich in fossil pollens like *Dermatobrevicolporites dermatus, Longapertites* sp., *Arecipites bellus, Crotonipollis densus, Cupuliferoipollenites ovatus, Cythidites australis, Matanomadhiasulcites maximus., Palmaepollenites communis, Proxapertites cersus, Rhombipollis spp., Tricolporopollenites* spp. Based on the occurrence of *Dermatobrevicolporites dermatus, Longaapertites triangulates, Longapertites retipilatus, Matanomadhiasulcites maximus, Rhombipollis* sp. and *Cythidites australis,* a Paleocene-Eocene age (Kar, 1985; Frederiksen, 1994; Samant and Mohabey, 2009; Saxena and Ranhotra, 2009; Samant et al., 2014) is assigned to the zone. The zone marks an increase in pollen diversity and abundance compared to the *Inapertisporites* spp. Abundance Zone. The presence of pollens like *Matanomadhiasulcites maximus, Longapertites retipilatus, Palmaepollenites communis, and Proxapertites cersus* suggest the vegetation of tropical-subtropical lowland, on steep hillocks.

Palynostraigraphic zones of the Ninama Basin show that the progression and change in palynofossils from bottom to top are influenced by the water quality, water depth, and climatic conditions, which have controlled the vegetation but the local parameters such as intermittent volcanic activity in the surrounding area cannot be ruled out. Finally, this volcanic activity has filled the Ninama Lake with lavas and, hence, there is no further development of the palynostratigraphic zone.

8.4 CHOTILA BASIN

The Chotila Basin Intertrappean contains a diverse group of palynofossils with restricted occurrences stratigraphically and numerous barren intervals. The lower part of the basin belonging to the Rangpar Formation, shows dominance of the fungal spores while the middle and upper parts belonging to the Chotila Chert and Bamanbor Formation are dominated by angiosperm pollens with fungal spores. The temporal distribution pattern of palynotaxa recovered from individual samples in the vertical sedimentary succession indicates three biozones (Fig. 8.2):

1. ***Palaeomycites* spp. Abundance Zone**

   Lithology: The vertical range of this biozone is confined to clay shale lithofacies belonging to Rangpar Formation.

   Position: Sample 25-38, CS facies, Rangpar Formation.

Palynoassemblage: The palynozone is marked by significant dominance of *Palaeomycites spp.* (60%) in sample no. 25-38. The biozone also comprises of *Proxapertites* spp.*, Frasnacritetrus indicus, Frasnacritetrus tougourdeavi, Hypoxylonites minimus, Inapertisporites maximus, Meliolinites spinksii, Palaeomycites acinus, Palaeomycites* spp.*, Pluricellaesporites planus, Polycellaesporonites psilatus, Staphlosporonites setlyi, Centropyxis aculata, Arcella arenaria* in descending order of abundance. The overall assemblage of the biozone is dominated by fungal spores with rare occurrences of pollens.

Upper limit: The upper limit of the biozone is marked by the appearance and abundance of *Proxapertites* spp.

Remarks: The overall assemblage is dominated by *Palaeomycites* spp. and fungal spores.

2. *Proxapertites* spp. Assemblage Zone

Lithology: The vertical range of this biozone is confined to laminated chert and massive chert lithofacies belonging to Chotila Chert.

Position: Sample 15-24, MC and LC facies, Chotila Chert.

Palynoassemblage: The palynozone is marked by significant dominance of *Proxapertites* spp. (50%) in sample no. 15-24. The biozone also comprises of *Dermatobrevicolporites dermatus, Proxapertites* spp.*, Tricolporopollenites spp., Diporisporonites sirmaurensis, Frasnacritetrus indicus, Frasnacritetrus tougourdeavi, Helicomminites salvinites, Hypoxylonites* sp.*, Inapertisporites kedvesii, Inapertisporites maximus, Palaeomycites* spp.*, Papulosporonites multicellatus, Pluricellaesporites* sp.*, Polycellaesporonites globatus, Polycellaesporonites psilatus, Polycellaesporites saxenae, Staphlosporonites setlyi, Centropyxis aculata, Pediastrum* spp. in descending order of abundance. The overall assemblage of the biozone is dominated by pollens and fungal spores.

Upper limit: The upper limit of the biozone is marked by the abundance of pollen taxa like *Florschuetzia* sp. and *Meliapollis* sp.

Lower limit: The lower limit of the biozone is marked by the dominance *Palaeomycites* spp.

Remarks: The overall assemblage of this zone is dominated by *Proxapertites* spp. and abundant fungal spores.

3. ***Florschuetzia rajpardiensis* Assemblage Zone**

Lithology: The vertical range of the biozone is confined to fossiliferous shaly sandstone, silty shale and clay shale lithofacies of the Bamanbor Formation.

Position: Sample 1-5, FSS lithofacies, Bamanbor Formation.

Palynoassemblage: The palynozone is marked by significant dominance of *Florschuetzia rajpardiensis* (60%) in sample no. 1-9. The biozone also comprises of*, Meliapollis ramanujamii, Monocolpopollenites plicatus, Rhoipites kutchensis, Dicellaesporites minutus, Hypoxylonites minimus, Hypoxylonites* sp.*, Inapertisporites maximus, Inapertisporites novus, Inapertisporites tetradus, Palaeomycites acinus, Palaeomycites* spp.*, Papulosporonites multicellatus, Pluricellaesporites planus, Pluricellaesporites* sp.*, Polycellaesporonites globatus, Centropyxis aculata*, *Arcella arenaria* and Lepidopteran scales in descending order of abundance. The overall assemblage of the biozone is dominated by pollens and fungal spores.

Lower limit: The lower limit of this biozone is marked by the abundance of *Dermatobrevicolporites dermatus* and *Proxapertites* sp.

Remarks: The overall assemblage of this zone is dominated by *Florschuetzia rajpardiensis, Meliapollis ramanujamii, Rhoipites kutchensis,* and various fungal spores.

8.5 CHOTILA BASIN: AGE AND ENVIRONMENTAL IMPLICATIONS

The Chotila Basin intertrappean succession is divided into four biozones stratigraphically in ascending order, 1. *Palaeomycites* spp. Abundance Zone, 2. *Proxapertites* spp. Assemblage Zone, 3. *Florschuetzia rajpardiensis* Assemblage Zone (Fig. 8.2). These zones are further commented for the age based on the presence of the characteristic palynofossils and also interpreted for the other environment parameters and climatic conditions based on elemental ratios of the associated lithofacies.

The lowermost zone, *Palaeomycites* spp. Abundance Zone, is dominated by *Palaeomycites* spp. and various other fungal elements like *Frasnacritetrus indicus, Frasnacritetrus tougourdeavi, Hypoxylonites minimus, Inapertisporites maximus, Meliolinites spinksii.* Based on the dominance of fungal spores and mycorrhizae, and the near absence of pollens and pteridophyte spores, a non-conducive and harsh environment, with less diversified vegetation during deposition of the sediments is also suggested for this zone. This biozone is comparable to the lowermost zone, *Palaeomycites* spp. Abundance Zone and *Inapertisporites* spp. Abundance Zone of the Ninama Basin. A Paleocene age is also assigned to the biozone, based on the occurrence of *Monocolpopollenites plicatus* (Saxena and Trivedi, 2009; Saxena, 2010; Singh, 2020). It is also probable that in both basins, the sedimentation was contemporaneous and the initial environmental condition was identical.

The lowermost zone, *Palaeomycites* spp. Abundance Zone is followed by *Proxapertites* spp. Assemblage Zone. It is dominated by the occurrence of *Proxapertites* spp. The zone is also characterised by fossil pollen like *Dermatobrevicolporites dermatus, Proxapertites* spp*.,* *Tricolporopollenites* spp., and *Diporisporonites sirmaurensis*. Based on the presence of pollens*,* a Paleocene-Eocene age is assigned to the biozone (Kar, 1985; Venkatachala et al., 1988; Martínez et al., 2016; Singh, 2020). The presence of vertebrate fossils like Fish and turtles also supports the Paleogene age (Borkar, 1975, 1984; Arratia et al., 2004). The pollens belonging to Bombaceae, and Araceae, moist pan-tropical vegetation during the sedimentation (Kapgate et al., 2011; Monga et al., 2015; Kumar et al., 2016; Huang et al., 2020).

The youngest biozone, *Florschuetzia rajpardiensis* Assemblage Zone, is dominated by the presence of *Meliapollis ramanujamii, Monocolpopollenites plicatus* and *Rhoipites kutchensis.* A Paleocene-Eocene age is suggested for the biozone based on the occurrences of Paleogene elements like *Meliapollis ramanujamii, Monocolpopollenites plicatus,* and *Rhoipites kutchensis* (Saxena and Trivedi, 2009; Saxena, 2010; Singh, 2020). The zone occurs in fossiliferous shaly sandstone facies of the Bamanbor Formation. With the presence of freshwater bivalves and gastropods in association with palynofossils, the environment became conducive to the growth of plants as well as animals. The geochemical analysis of the associated lithofacies suggests deep, fresh to moderately/low brackish water and warm, humid tropical climatic conditions. The uppermost of the Bamanbor Formation is completely barren and does not show the development of any type of plant life, may have been influenced by volcanic activity, and finally lake was covered by the lava flows.

The palynoflora of the zone marks a characteristic rise in the pollens, also suggesting that the new vegetation, had emerged, also comparable and probably contemporous to *Rhombipollis geniculatus* - *Proxapertites* spp. Assemblage Zone and uppermost biozone *Dermatobrevicolporites dermatus* - *Longapertites* sp. Assemblage Zone of Ninama basin. The palynofossils of both the basins suggest sedimentation was contemporaneous, during the Paleogene time.

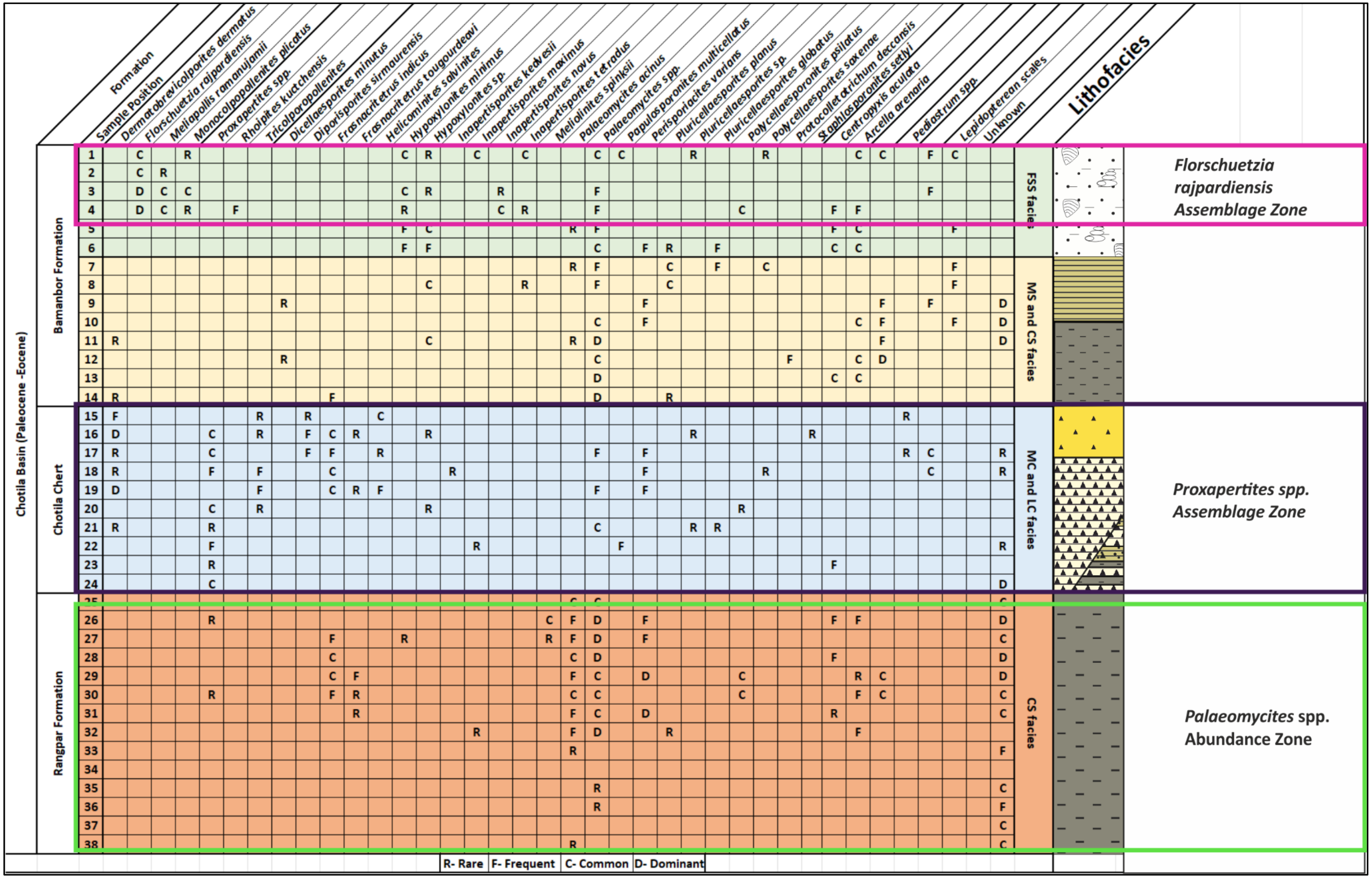

Fig. 8.2 Generalized litholog shows sample positions, lithostratigraphy and lithofacies of the Chotila Intertrappeans. Palynofossils distribution shows their relative abundance in the systematically collected samples with their palynostratigraphic zonation. Chotila Chert and Bamanbor Formaion contain abundant and most diverse palynofossils as compared to lower Rangpar Formation.