

CHAPTER-7

PALYNOLOGY

7.1 INTRODUCTION

Palynology is the scientific study of microscopic organic particles known as "palynomorphs" found in sedimentary rocks, soils, and various natural environments. A few morphological and ultrastructural features of spores and pollen grains have provided a wealth of information that have been important in inferring phylogenetic relationships of plants (Simpson, 2020). These palynomorphs provide invaluable insights into Earth's geological history, past climates, and the evolution of plant and microbial life.

Spores:

Spores are one of the fundamental types of palynomorphs. They are small, single-celled reproductive structures produced by certain plants, including ferns, mosses, and some non-seed-producing vascular plants. Spores are equipped with protective layers and are dispersed into the environment to give rise to new plants under favorable conditions. The morphology of spores can vary significantly between different plant groups, making them crucial in identifying ancient vegetation and reconstructing paleoclimates.

Pollen Grains:

Pollen grains are another significant category of palynomorphs. They are the male reproductive structures produced by seed plants (angiosperms and gymnosperms). Pollen is well-known for its resistance to decay and its characteristic shapes, which can be used to identify plant species. Palynologists often study pollen to track changes in vegetation over time, infer climate conditions, and understand plant evolution and migration patterns.

Dinoflagellates:

Dinoflagellates are single-celled, photosynthetic protists found in marine and freshwater environments. They produce distinctive, often ornamented, cysts that are preserved as palynomorphs in sedimentary rocks. The study of dinoflagellate cysts is essential in paleoceanography, as their presence and composition can provide information about ancient ocean conditions, including water temperature, salinity, and nutrient availability.

Scolecodonts:

Scolecodonts are the jaws or mouthparts of extinct marine polychaete worms. These microscopic structures are durable and widely distributed in sedimentary rocks, especially in marine sediments. They serve as valuable indicators of past marine ecosystems, providing insights into the diversity and ecology of ancient polychaete worms and their coexistence with other organisms.

Phytoclasts:

Phytoclasts are the remnants of plant tissues, such as cell walls and cuticles, that have been preserved in sedimentary rocks. They are often used to identify ancient plant species and reconstruct paleoenvironments. Phytoclasts can be found in various forms, including woody tissues, leaves, and other plant structures.

Amorphous Organic Matter:

Amorphous Organic Matter (AOM) is a catch-all term for organic materials that lack a definite shape or structure, making them challenging to categorize using conventional methods. AOM can encompass various organic compounds, such as degraded plant material, microorganisms, and other organic debris. Palynologists often study AOM to gain insights into the general composition of organic matter in sedimentary rocks and its role in preserving other palynomorphs.

In summary, palynology is a critical field in earth sciences that utilizes a diverse range of palynomorphs to reconstruct the Earth's history, including past climates, evolution of plants, vegetation, and ecosystems. These microscopic particles, including spores, pollen, dinoflagellates, scolecodonts, phytoclasts, and amorphous organic matter, are valuable tools for unravelling the mysteries of our planet's past. Palynomorphs have economic significance in petroleum and coal exploration where they are used for environmental interpretation, local and regional correlation, dating the age of the strata and as a thermometry to understand the maturity of the organic matter.

7.2 TAXONOMY

Binomial nomenclature has been used for all recognized species. The genera and species have been considered as artificial taxonomic units based on the morphological characteristics of the palynomorphs. The natural plant affinities have been recorded whenever

feasible. The form genera and species have been classified into supra-generic groups in the Artificial Classification. It is acknowledged that this current study does not address the complex issues of Nomenclature and Classification in detail. However, a concise overview is provided to explain the organization of the systematic descriptions of the scattered palynomorphs.

The nomenclature of fossil spores (*sporae dispersae*) adheres to the regulations outlined in the International Code of Botanical Nomenclature (ICBN, Greuter and Hawksworth et al. 2001).

This code formally acknowledges entire plant taxa (*eutaxa*), as well as form-genera and species (*parataxa*), which include distributed spores, pollen grains, dissociated leaves, roots, fruits, seeds, and other plant parts.

Morphology is the sole method for categorizing scattered spores. These spores are classified based on the characteristics of their germinal aperture, equatorial contour, wall stratification, sculpting, and any structural modification or thickness of the spore wall. Generic names frequently indicate the structure or perceived similarities of the forms; however, this can sometimes be deceptive. Hughes and Richards, (1989) proposed the rejection of the Linnean System of taxonomy and nomenclature, proposing instead a system grounded in biorecords. Despite its greater flexibility, this approach has not been implemented. Jansonius and Hills (1981) together with supplementary materials offer a comprehensive inventory and detailed explanations of fossil spore and pollen genera.

The classification scheme for spores introduced by Potonié (Potonié & Kremp 1954) is the most commonly used, with further modifications.

Three schemes for the classification of fossil spores and pollens have been suggested,

1. Natural system:

The classification technique relies on comparing fossil spores and pollen grains with their modern counterparts. The technique is more effective in identifying dispersed spores/pollens from Neogene and Quaternary strata. However, it is not as successful in older sediments, as the bulk of palynofossils from Palaeozoic, Mesozoic, and Paleogene sediments are either unknown or their affinity is questionable.

2. Artificial system:

Dispersed spore/pollen grains are categorized only based on their physical characteristics and are assigned artificial general and specific names, without considering their evolutionary relationship within the artificial system. The strategy is convenient and straightforward to implement in stratigraphic studies. This system is suitable for stratigraphic purposes, serving as a semi-natural categorization system for Paleogene and Neogene strata and a morphological system for Paleozoic sediments. Ibrahim (1933) introduced a synthetic scheme of categorization for fossil spores and pollen grains. He identified three primary categories, namely Triletes, Aletes, and Monoletes, which were then further subdivided into smaller groups.

A highly satisfactory and extensively employed Classification System was suggested by Potonié and Kremp (1954), subsequently modified by Potonié (1955, 1956), and further revised in conformity with the International Code of Botanical Nomenclature by Potonié (1958, 1960, 1966, 1970). This system prioritized the inclusion of established genera and species, whereas the higher-level groups were determined based on descriptive morphological characteristics such as aperture, lip, equatorial features, and wall stratification. Every division within the categorization system is established on multiple diagnostic characteristics.

Dettman (1963) suggested a modification to the classification system of Potonié and Kremp (1954) for the Anteturma-Sporites. In this system, Dettmann (1963) utilized a single diagnostic characteristic to classify the supergeneric categories. For instance, the initial division into Turma was determined by the type of aperture, the subsequent division into Suprasub-turma was based on wall stratification, and the third division into Subturma was determined by equatorial features, among others. This system has garnered extensive support from palaeopalynologists. In this classification system, artificial categories called Infraturma, Subturma, Turma, and Anteturma are introduced to group diverse artificial genera. The suprageneric groups are determined by the morphological characteristics of spores and pollen grains, including aperture nature, wall stratification, exine thickness, and exine sculpting.

In addition to the aforementioned approaches for classifying Sporae Dispersae, other alternative proposals have been put forth by different researchers at different times. Notable recommendations have been put forth by Naumova (1939), Schopf, Wilson, and

Bentall (1944), Erdtman (1947), Pant (1954), Rouse (1957), Krutzsch (1959), and Erdtman and Straka (1961).

In this work, the spores and pollen grains have been organized in a systematic manner, using the classification method provided by Potonié and Kremp (1954, 1955, 1956), which was later modified by Potonié (1958, 1960, 1966, 1970).

3. Combination system:

The classification of fossil spores and pollen grains is determined by both their physical characteristics and their evolutionary relationship. The generic names are derived from existing plant genera and blended with newly created species names. The use of both natural generic names and artificial specific names in this system results in taxonomic ambiguity.

The classification system employed in this study adheres to Potonié and Kremp (1954, 1955), as well as Potonié (1956, 1958, 1960, 1966). The systematic approach involves the description of recorded species of spores and pollen grains, highlighting their morphological characteristics observed under a high-power light microscope. These morphological features are compared with diagnostic characters from earlier authors. The terminology and Encyclopedia of Kremp (1968) and Punt (2007) are used for fossil spores and pollen grains. Occurrences are documented in Palaeocene, Eocene, Oligocene, and Miocene horizons of India, as listed in the catalogue of fossil plants by Lakhanpal et al. (1976) and Saxena & Trivedi (2006). Fossil fungi, often lacking distinct features of extant taxa, pose challenges in classification. Elsik (1976) proposed a comprehensive taxonomy for fossil fungal spores, introducing artificial supra-generic categories. Microthyriaceous fungi's fruit bodies, known as Ascocarps, are categorized under Fungi Imperfecti in the Artificial System based on cell number and aperture presence. The classification of fossil fungi is based on Saxena and Tripathi (2011).

7.3 SYSTEMATIC DESCRIPTION OF PALYNOTAXA

7.3.1 Pteridophytic spores and pollens

PTERIDOPHYTIC SPORES

Turma- Triletes Potonié & Kremp, 1954

The Triletes are spores that have a trilete aperture, but do not possess a cingulum or zona.

Subturma- Azonotriletes (Luber) Dettmann, 1963

The Azonotriletes are triletes that lack any structural complexity in the form of proximal thickness.

Infraturma- Laevigati Potonié, 1956

The Laevigati encompass both punctuate and laevigate sculptural variations of the Azonotriletes.

Anteturma: Sporites H. Potonié, 1893

Turma: Triletes Potonié & Kremp, 1954

Subturma: Azonotriletes (Luber) Dettmann, 1963

Infraturma: Laevigati Potonié, 1956

Genus: *Cyathiditis* Couper, 1953

Species: *Cyathiditis australis* Couper, 1953

(Plate 7.1a)

Description: The spores are triangular with rounded apices and slightly concave interapical borders. The laesurae are clearly visible and extend up to two-thirds of the spore radius. The size varies within the range of 20 μm . The exine is 1.5–2 μm thick and is psilate (Couper, 1953).

Affinity: Cyatheaceae

Age: Palaeocene-early Miocene

Occurrence: Ninama Limestone

Genus- *Hammenisporis* Saxena and Trivedi, 2009

Species: *Hammenisporis susannae* Saxena and Trivedi, 2009

(Plate 7.1b)

Description: Medium-sized, triangular spores (25-35 μm in polar view). Trilete mark is distinct, evenly broad, half to three-fourths radius, commissure distinct. Exine striate, striations more than 7, running parallel but never coalescing, arising at inter-radial area or ray ends and

continuing distal side as successive concentric rings, sparsely or closely placed, psilate, sometimes ornamented and branched (Saxena and Trivedi, 2009).

Affinity: Parkeriaceae

Distribution: Tropical

Age: Lower Eocene

Occurrence: Ninama Limestone

ANGIOSPERM POLLENS

The Pollenites are classified by aperture and sacchi presence or absence.

Turma- Plicates (Naumova) Potonié, 1960

The Plicates are Pollenites possessing colpi but without sacchi.

Subturma- Monocolpates Iversen & Troels-Smith, 1950

The Monocolpates are the Plicates with a single distal transverse colpus and without any proximal aperture.

Infraturma– Monoptyches (Naumova) Potonié, 1958

The Monoptyches are the Plicates that have a single radially arranged colpi.

Anteturma: Pollenites Potonié, 1931

Turma: Plicates (Naumova) Potonié, 1960

Subturma: Monocolpates Iversen & Troels-Smith, 1950

Infraturma: Monoptyches (Naumova) Potonié, 1958

Genus: *Arecipites* Wodehouse (1933)

Species: *Arecipites bellus* Sah and Kar, 1970

(Plate 7.1c)

Description: Pollen grains are oval with rounded lateral edges and a somewhat pointed end, measuring 50-60×25-28 μm. Colpus closed or open. Sexine thicker than nexine, exine 1-2 μm. Each punctum is 2–3 μm in diameter, densely packed, and evenly dispersed (Sah and Kar, 1970).

Affinity: Arecaceae

Age: Late Paleocene-Middle Eocene

Occurrence: Bamanbor Formation

Genus: *Palmaepollenites* Potonié, 1951

Species: *Palmaepollenites communis* Venkatachala and Kar, 1969

(Plate 7.1d)

Description: Pollen grains are oblong with rounded to pointed ends. Size: 30-40x20µm. Monocolpate, colpus distinct, middle broader, ends tapering, boat-shaped, never reaching edges. Laevigate, thick exine (Venkatachala and Kar, 1969).

Affinity: *Iguanura geonomaeformis* of Arecaceae

Age: Paleocene-early Oligocene

Occurrence: Ninama Limestone

Genus- *Palmidites* Couper

Species: *Palmidites plicatus* Singh, 1974

(Plate 7.1e)

Description: Pollen grains are oval to elliptical, 60-75 × 25-30µm in size. Monocolpate, colpus distinct, indistinct due to fold overlap, sometimes well-developed folds across colpus. Laevigate or somewhat intrastriated exine 1–2 µm thick (Singh, 1974).

Affinity: Arecaceae

Age: Late Palaeocene-Miocene

Occurrence: Ninama Limestone

Infraturma- *Retectines* (Malawkina) Potonié, 1958

Genus: *Longapertites* spp. Germeraad, Hopping & Muller, 1968

(Plate 7.1f-h)

Species: *Longapertites retipilatus* Kar, 1985

(Plate 7.1g)

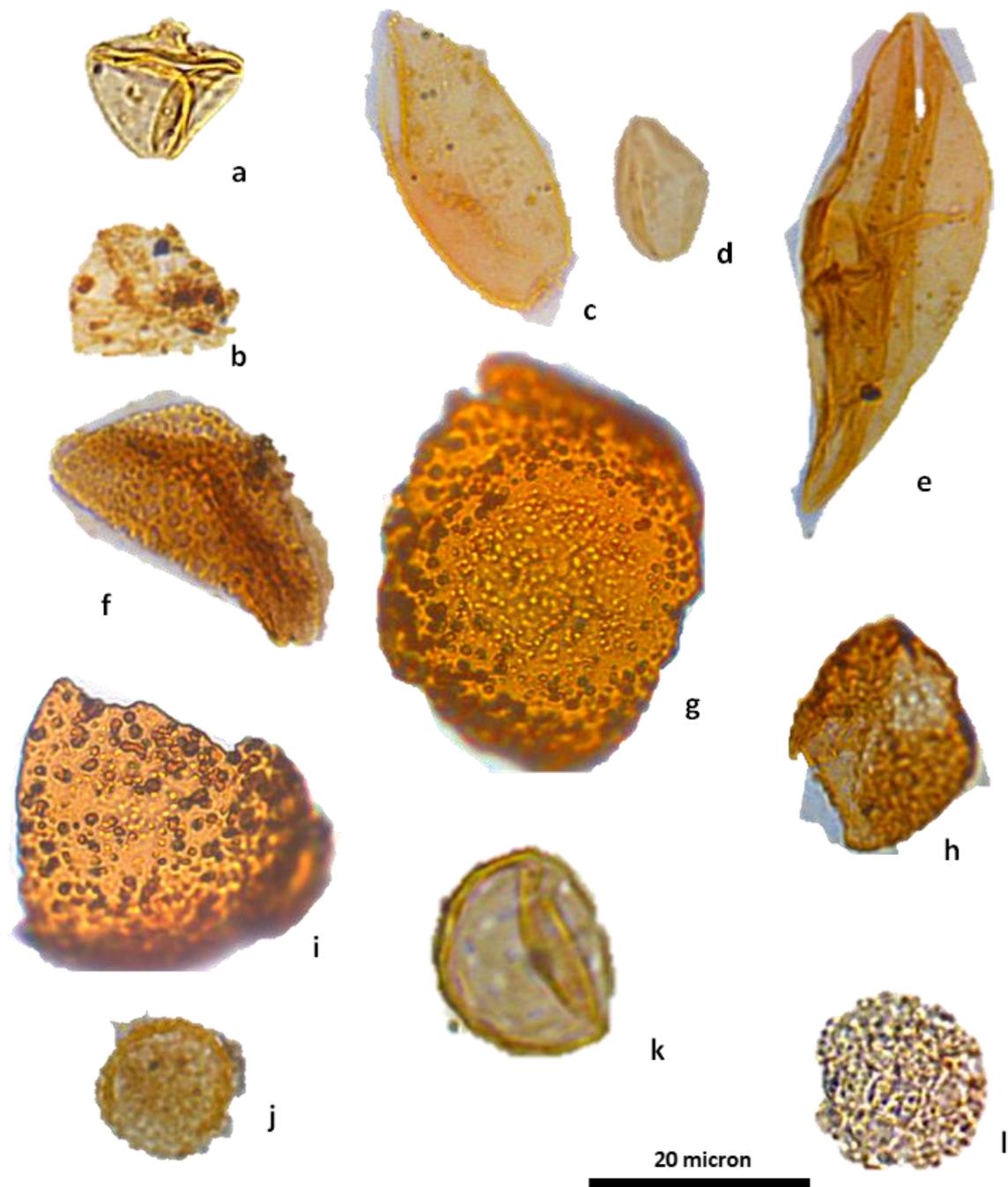


Plate. 7.1 a. *Cythidites australis*, NL-NB, b. *Hammenisporis susannae*, NL-NB, c. *Arecipites bellus*, NL-NB, d. *Palmaepollenites communis*, NL-NB, e. *Palmidites sp.* NL-NB, f. *Longapertites sp.*, NL-NB, g. *Longapertites retipilatus*, NL-NB, h. *Longapertites triangulates*, NL-NB i. *Matanomadhiasulcites maximus*, NL-NB, j-k. *Proxapertites cersus*, NL-NB, l. *Proxapertites crassimurus*, NL-NB, (NL- Ninama Limestone, SF- Sukhbhadar Formation, BF- Bamanbor Formation, CC- Chotila Chert, RF- Rangpar Formation, NB- Ninama Basin, CB- Chotila Basin).

Description: Monad, Monosulcate, heteropolar, oblate pollen with a roughly round outline in equatorial view, measuring 55-60×25-30µm. Sulcus long, reaching to the proximal surface, occupying two thirds of the circumference, infolded margins; perforate (Kar, 1985).

Affinity: *Eugeissona* of Arecaceae

Age: Paleocene-Pliocene

Occurrence: Ninama Limestone

Species: *Longapertites triangulates* Samant and Phadtare, 1997

(Plate 7.1h)

Description: Pollen grains range from triangular to subtriangular, measuring 50-60µm. Monosulcate, microreticulate to reticulate-retipilate, united pilae heads with large flat ends, forming columella (Samant and Phadtare, 1997).

Affinity: *Eugeissona* of Arecaceae

Age: Palaeocene-early Miocene

Occurrence: Ninama Limestone

Genus: *Matanomadhiasulcites* Kar

Species: *Matanomadhiasulcites maximus* Kar, 1985

(Plate 7.1i)

Description: Pollen grains are 35-50 µm in size, oval to elliptical, monosulcate, and have a broad sulcus from pole to pole. A negative reticulum with exine 1–3 µm thick, retipilate to retibaculate, and pila 2–5 µm long, is seen on the surface, with densely distributed bacula (Kar, 1985).

Affinity: Annonaceae / Liliaceae

Age: Late Palaeocene-Early Eocene

Occurrence: Ninama Limestone, Sukhbhadar Formation

Subturma: *Dicolpates* Erdtman, 1947

Infraturma: *Sphaerozonisulcates* Venkatachala & Kar, 1967

Genus: *Proxapertites roxapertites* van der Hammen (1956)

Species: *Proxapertites cersus* Van Hoeken-Klinkenberg, 1966

(Plate 7.1j-k)

Description: Pollen grain is 15–30 μm in size. It is subspheroidal–spheroidal and reticulate, with microreticulate ornamentation.

Affinity: Araceae

Age: Cretaceous-Pliocene

Occurrence: Ninama Limestone

Species: *Proxapertites crassimurus* Singh, 1975

(Plate 7.1l)

Description: Pollen grains circular in shape, size is 25–35 μm . Zonisulcate, sulcus not visible prominently. Exine, reticulate, crassimurate, muri about 1.5 μm broad, lumina of various shapes.

Affinity: Araceae

Age: Late Palaeocene-Late Oligocene

Occurrence: Ninama Limestone

Subturma- Ptychotriporines (Naumova) Potonié, 1966

The Ptychotriporines are the Plicates that have three radially symmetrical colpi, each colpi is porate.

Infraturma- Prolati Ertman, 1943

The Ptychotriporines in which polar axis is longer than the equatorial axis.

Genus: *Dermatobrevicolporites* Kar, 1985

(Plate 7.2 a-b)

Species: *Dermatobrevicolporites dermatus* Kar, 1985

(Plate 7.2 b)

Description: Pollen grains triangular to sub-triangular in shape, 25–30 μm in size. Tricolporate, colpi short, pores well developed, 4–5 μm in diameter, ovoidal in shape, Exine 3.5–5 μm thick, psilate, exine thicker than nexine (Kar, 1985).

Affinity: Bombacaceae

Age: Palaeocene-Late Oligocene

Occurrence: Ninama Limestone, Chotila Chert, Bamanbor Formation

Genus: *Lakiapollis* Venkatachala and Kar, 1969

Species: *Lakiapollis ovatus* Venkatachala and Kar, 1969

(Plate 7.2c)

Description: Pollen is subcircular, 50-70 μm in size, tribrevicolporate, and colpi are tiny Fully developed oval-elliptical pores with thicker outer borders. Exine, being psilate and unevenly folded, can be up to 2.5 μm thick and thicker than nexine (Venkatachala and Kar, 1969).

Affinity: Bombacaceae

Age: Palaeocene-early Miocene

Occurrence: Ninama Limestone

Genus: *Meliapollis* Sah and Kar, 1970

Species: *Meliapollis ramanujamii* Sah and Kar, 1970

(Plate 7.2d)

Description: Small colpi, funnel-shaped, Tetracolporate subcircular to circular, pollen grain. Fully formed pores; thickened margin, laevigate (Sah and Kar, 1970).

Age: Paleocene-Early Eocene

Occurrence: Bamanbor Formation

Genus: *Rhoipites* Wodehouse, 1933

Species: *Rhoipites kuctchensis* Venkatachala and Kar, 1969

(Plate 7.2 e)

Description: In equatorial view, pollen grains are circular, tricolporate, and prolate, measuring 40-50 μm Colpi long, sinous, pores visible, intramicroreticulate ornamentation. Exine is 2 μm thick, tectate, with hardly discernible columella and smooth surface sculptures (Venkatachala and Kar, 1969).

Affinity: Anacardiaceae

Age: Palaeocene-Late Oligocene

Occurrence: Bamanbor Formation

Turma Stephanocolporates

Genus: *Tricolporopollenites* Thomson and Pflug, 1953

Species: *Tricolporopollenites* spp. Thomson and Pflug, 1953

(Plate 7.2, f-g)

Description: Pollen grain oval-oblate, tricolpate, colpi with close-spaced baculae. Reticulate exine, varied lumina. Size: 15-25 μm .

Affinity: Fagaceae

Age: Unknown

Occurrence: Ninama Limestone, Sukhbhadar Formation, Chotila Chert

ANGIOSPERMAE

Genus: *Aquilapollenites* Srivastava, 1968

Species: *Aquilapollenites ovatus* Hofmann and Zetter, 2007

(Plate 7.2 h)

Description: Pollen grains are tricolpate with long, subisopolar and three short, wedge-shaped equatorial segments. Polar and equatorial projections are equally perforate and have short, rounded spines (0.2–0.3 μm) that are regularly but widely separated. Polar sections are smooth and mildly perforate (Hofmann and Zetter, 2007).

Affinity: Probably Loranthaceae and Santalaceae

Forest type: Subtropical to warm-temperate forests

Age: Maastrichtian- Early Eocene

Occurrence: Ninama Limestone

PROLATI

Genus: *Araliaceoipollenites* Potonié 1960

Species: *Araliaceoipollenites psilatus* Dutta and Sah, 1970

(Plate 7.2 i)

Description: Size: 25-34 μm ; amb round-triangular to sub-prolate. 3-colporate, angular aperture, colpi distinct, long, tenuimarginate; ora thin, apparently slightly elongate; exine thick, endoexinal thickenings visible in polar and equatorial views, surface sculpture psilate (Dutta and Sah, 1970).

Affinity: Araliaceae

Age: Paleocene

Occurrence: Ninama Limestone

Species: *Araliaceoipollenites reticulatus* Dutta and Sah, 1970

(Plate 7.2 j)

Description: Size: 25-34 μm ; subprolate equatorially, oblate-spheroidal polarly; 3-zonaperturate, colporate, colpi distinct, deep; faint pores; thick exine, sexine as thick as nexine; coarsely pitted-reticulate surface sculpture; meshes distinct at poles, becoming faint or indistinct towards equator (Dutta and Sah, 1970).

Affinity: Araliaceae

Age: Paleocene

Occurrence: Ninama Limestone

PTYCHOTRIPORINES

Genus: *Barringtoniapollenites* Kar and Sharma, 2001

Species: *Barringtoniapollenites retibaculatus* Kar and Sharma, 2001

(Plate 7.3 a)

Description: Pollen oval-subcircular, 40-30 x 15-20 μm , thick exine, well-developed sexines and nexins, retipilate, swelling ends, pseudoreticulation, and end-to-end colpi (Kar and Sharma, 2001)

Affinity: Barringtonia (Barringtoniaceae)

Forest type: Tress of coastal swamps

Age: Late Palaeocene-Early Eocene

Occurrence: Ninama Limestone

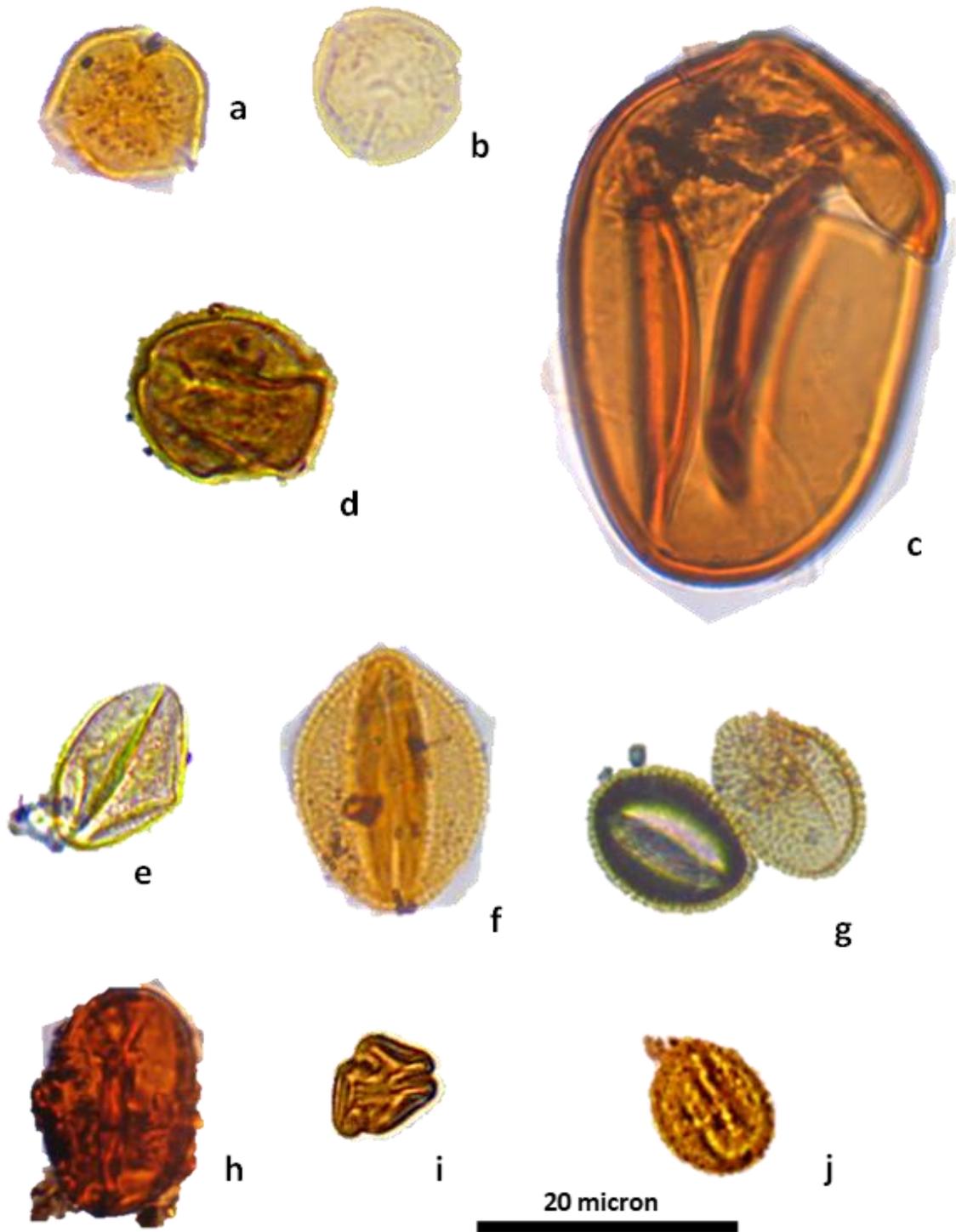


Plate 7.2 a. *Dermatobrevicolporites* sp., NL-NB, b. *Dermatobrevicolporites dermatus*, CC-CB, c. *Lakiapollis ovatus*, NL-NB, d. *Meliapollis ramanujamii*, BF-CB, e. *Rhoipites kutchensis*, BF-CB, f-g. *Tricolporopollenites* spp, SF-NB, h. *Aquilapollenites ovatus*, NL-NB, i. *Araliaceoipollenites psilatus*, NL-NB, j. *Araliaceoipollenites reticulatus*, NL-NB.

Genus: *Cupuliferoipollenites* Potonié 1960

Species: *Cupuliferoipollenites ovatus* Venkatachala and Kar, 1992

(Plate 7.3 b)

Description: Pollen grain oval, small size 10-15 x 20-25 μm , 3 colpi, Colpi long, extending end to end, pore distinct, elongate, exine 1 μm thick, weakly intrastriated (Venkatachala and Kar, 1992).

Affinity: Uncertain

Forest type: Temperate broad-leaved forest

Age: Eocene-Miocene

Occurrence: Ninama Limestone

Species: *Cupuliferoipollenites psillus* Potonié 1951

(Plate 7.3 c)

Description: Pollen grain oval, elongated, size 15-20 μm , 3 colpi, Colpi long, extending end to end, ends round, distinct pore, elongated, exine 1 μm thick and conspicuous, weakly intrastriated (Potonié, 1951).

Affinity: Uncertain

Forest type: Temperate broad-leaved forest

Age: Eocene-Miocene

Occurrence: Ninama Limestone

ALETES

Genus: *Incrotonipollis* Jansonius and Hills, 1981

Species: *Incrotonipollis neyvelii* Baksi, Deb and Siddhanta, 1979

(Plate 7.3 d)

Description: Pollen grains range from 30-45 μm in size, subspheroidal, exine intectate, and 1-3 μm thick. Clavae occur on top of muroid ridges, encircling every muroid region with 6 polygonal clavae.

Affinity: *Jatropha* (Euphorbiaceae)

Age: Paleocene- Eocene

Occurrence: Ninama Limestone

TRIPTYCHES

Genus: *Cupanieidites* Cookson and Pike, 1954

Species: *Cupanieidites flaccidiformis* Venkatachala and Rawat 1972

(Plate 7.3 e)

Description: Trisyncolporate in round-triangular amb with convex sides, 15-25 μm . Arci prominent, no polar island. Refined pores. Exine thickness is 1 μm , thicker than nexine, and with minimal reticulate, flangy, and equatorial flanges in the mesocolpium area (Venkatachala and Rawat, 1972).

Affinity: Sapindaceae

Age: Paleocene- Eocene

Occurrence: Ninama Limestone

COSTATI

Genus: *Ephedripites* sp. Potonié 1958

(Plate 7.3 f)

Description: In equatorial view, oblate pollen grain, fusiform/ellipsoidal shape. Size, 15-25 μm , diameter: 30 μm . Double plicae reach equatorial zones. The exine is 1 to 3 μm thick.

Affinity: Ephedraceae

Forest type: Shrub

Age: Paleocene-Eocene

Occurrence: Sukhbhadar Formation

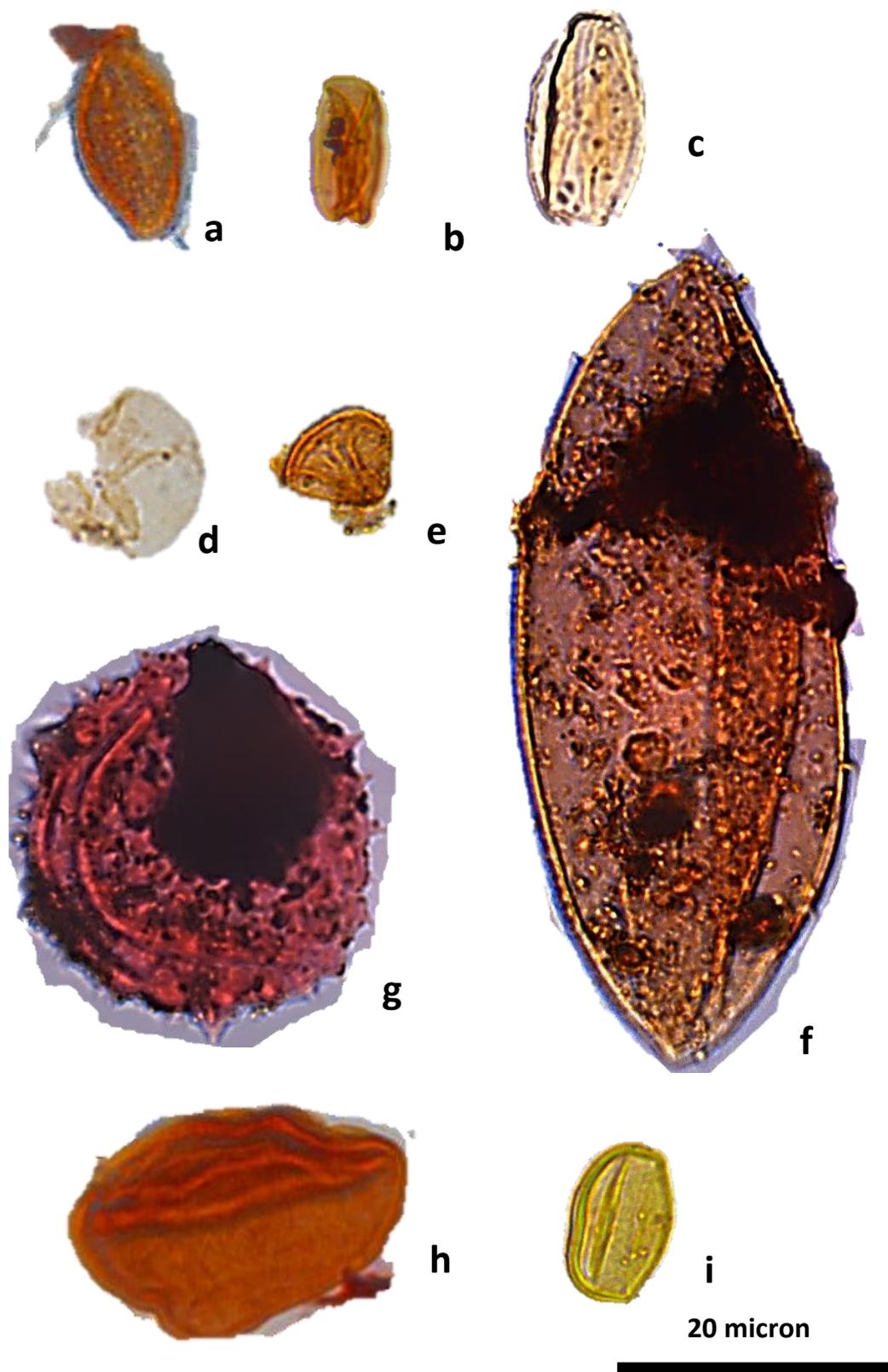


Plate 7.3 a. *Barringtoniapollenites retibaculatus*, NL-NB, b. *Cupuliferoipollenites ovatus*, NL-NB, SF-NB, c. *Cupuliferoipollenites psillus*, NL-NB, d. *Incrotonipollis neyvelii*, NL-NB e. *Cupanieidites flaccidiformis*, NL-NB, f. *Ephedripites* sp. SF-NB, g. *Malvacearumpollis baconyensis*, NL-NB, h. *Monocolpopollenites* sp. NL-NB, i. *Monocolpopollenites plicatus*, BF-CB.

POLYPORINES

Genus: *Malvacearumpollis* Nagy 1962

Species: *Malvacearumpollis baconyensis* Nagy, 1962

(Plate 7.3 g)

Description: Large (85–105 μm) globular pollen grains, the surface pilate and covered with spines in fairly regular, 8–14 μm large intervals. The spines are conical, tapering into acuminate tips, 6–12 μm large, rising on a bulging base formed of exine.

Affinity: Malvaceae

Habitat: Coastal Palms

Age: Eocene-Miocene

Occurrence: Ninama Limestone

MONOPTYCHES

Genus: *Monocolpopollenites* sp. Thomson and Pflug, 1953

(Plate 7.3 h-i)

Species: *Monocolpopollenites plicatus* Saxena, 2010

(Plate 7.3 i)

Description: Pollen grain elliptical, 48–60 x 20–40 μm . Monocolpate, colpus extending from end to end, associated with folds; exine more or less laevigate, weakly intrastriated (Saxena, 2010).

Affinity: Arecaceae

Age: Paleocene-Miocene

Occurrence: Ninama Limestone, Bamanbor Formation

TRIPORINES

Genus: *Florschuetzia* Germeraad, Hopping and Muller, 1968

Species: *Florschuetzia rajpardiensis* Samant and Phadtare, 1997

(Plate 7.4 a)

Description: Radial, isopolar, trilobate monad pollen; exine tectate in equatorial view; columellae indistinct; sculpture scabrate.

Affinity: Sonneratiaceae

Habitat: Fresh or brackishwater swamps

Age: Early Eocene

Occurrence: Bamanbor Formation

Genus: *Mulleripollis* Baksi and Deb, 1976

Species: *Mulleripollis bolporensis* Baksi and Deb, 1976

(Plate 7.4 b)

Description: Pollen grains are isopolar, prolate, and jointed in loose tetrahedral cross tetrads, with proximal poles 35-40 μm and rounded ends. Tricolpate with exinous folds and long, narrow, slit-like colpi almost reaching the poles. Exine is 1 μm thick, tectate, densely striate, with ridges and grooves under 0.5 μm width.

Affinity: Uncertain

Age: Palaeocene–Eocene

Occurrence: Ninama Limestone

Genus: *Rhombipollis* Frederiksen, 1994

Species: *Rhombipollis geniculatus* Frederiksen, 1994

(Plate 7.4 c-e)

Description: Pollen tricolporate has a rhomboidal form, a robust geniculus, columellate and punctate, and a 1-3 μm thick exine, size 10-15 μm (Frederiksen, 1994).

Affinity: Unknown

Age: Middle-Late Paleocene

Occurrence: Ninama Limestone

Genus: *Yeguapollis* Elsik, 1974

Species: *Yeguapollis* sp. Elsik, 1974

(Plate 7.4 f-g)

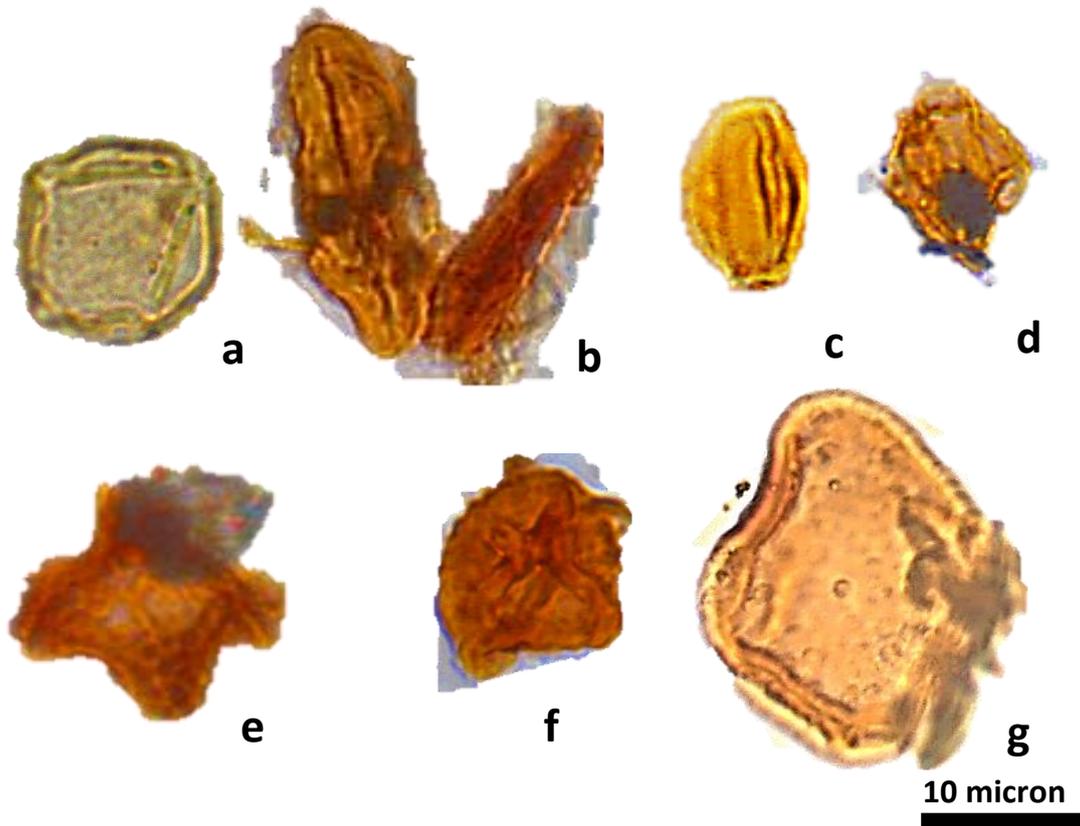


Plate 5.4, a. *Florschuetzia rajpardiensis*, BF-CB, b. *Mulleripollis bolporensis*, BF-CB, c-e. *Rhombipollis geniculatus*, NL-NB, f-g. *Yeguapollis* sp. NL-NB.

Description: Polar axis 30-40 μm , equatorial 20-25 μm , Prolate, grain ends flattened. Nexine is thin throughout, whereas exine is 2 μm thick at the edges. Finely columellate and punctate to finely reticulate sexine at grain ends. Colpi is long and thin (Elsik, 1974).

Affinity: Lythraceae

Age: Middle-Late Paleocene

Occurrence: Ninama Limestone

7.3.2 Fungal spores and fungal elements

Kingdom: Fungi

Phylum: Ascomycota

Order: Dothideales

Genus: *Perisporiacites* Felix, 1894

Species: *Perisporiacites varians* Sahni and Rao, 1943

(Plate 7.5 a-c)

Description: The perithecia are black, spherical to ellipsoid, 85-95 μm long and 70-80 μm wide, with a reticulum of irregular-shaped cells on the surface. Mycelium branching, cells longer than broad, sometimes elliptical, producing small chains with hook-like clamps (Sahni and Rao, 1943).

Age: Early Tertiary

Occurrence: Sukhbhadar Formation, Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation

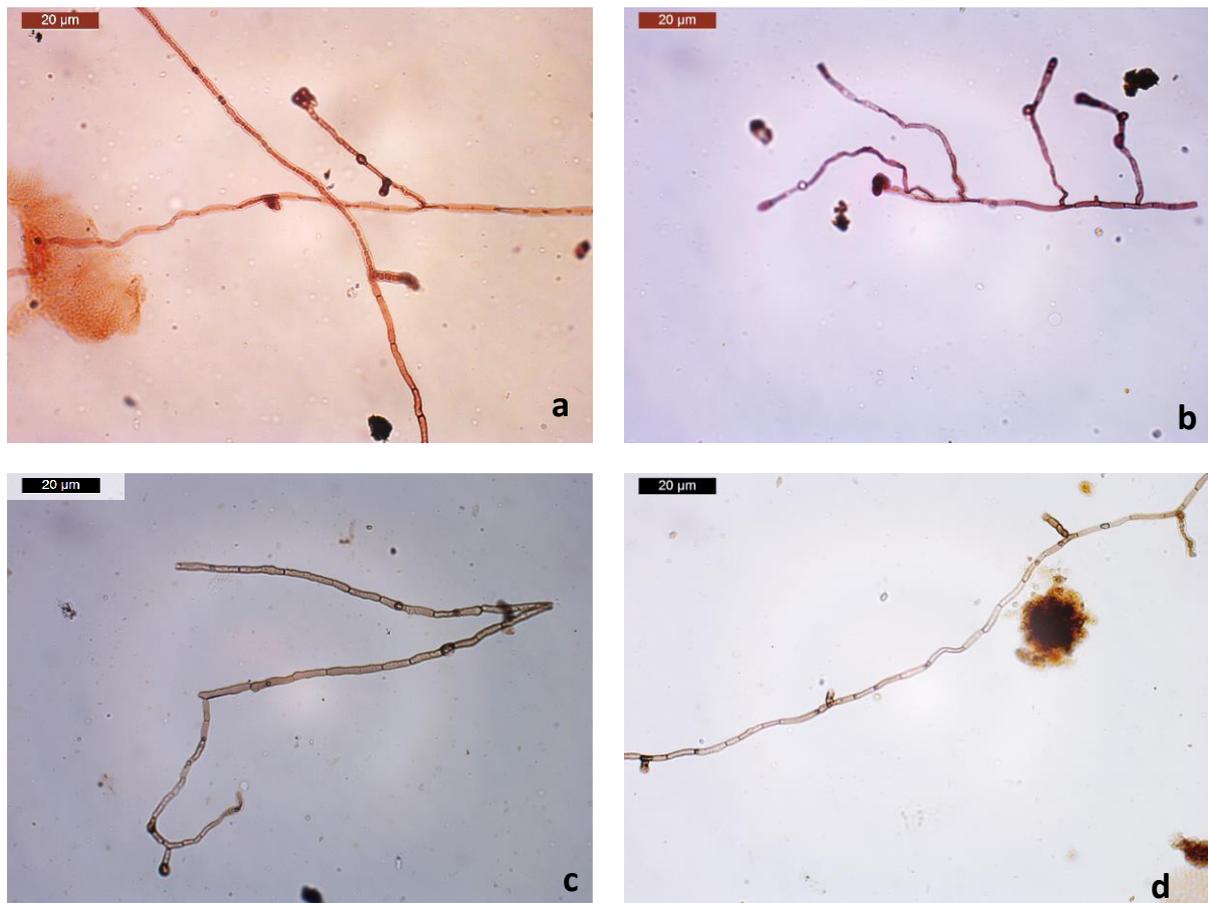


Plate 7.5, a-c. *Perisporiacites varians*, a. NL-NB, b. CC-CB, c. RF- CB, d. *Meliolinites spinksii* RF-CB.

Order: Meliolales

Family: Meliolaceae

Genus: *Meliolinites* Selkirk, 1975

Species: *Meliolinites spinksii* Selkirk, 1975

(Plate 7.5 d)

Description: Meliolaceae-like mycelium and spores. Mycelial setae gone. Immature colonies, and thin adult colonies. Hyphae straight, oppositely to right-angle branching. Hyphal cells (5-10 µm) form capitate hyphopodia at their distal ends by the side. Cuneate cylindrical stalk cells. Whole, oblong-ovoid head cells (Selkirk, 1975).

Age: Tertiary-Neogene

Occurrence: Sukhbhadar Formation, Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation

FUNGI IMPERFECTI

Family: Phragmosporae

Genus: *Ceratohirudispora* Kar, Mandoakar and Kar, 2010

Species: *Ceratohirudispora triradiata* Kar, Mandoakar and Kar, 2010

(Plate 7.6 a)

Description: Hyphomycetaceous conidia with triradiate appearance, three arms, uneven length and size, septate septa, 4-8 cells, 1 µm conidia wall, and laevigate.

Age: Miocene

Occurrence: Sukhbhadar Formation

Genus: *Pluricellaesporites* Elsik and Jansonius, 1974

Species: *Pluricellaesporites globatus* Samant, 2009

(Plate 7.6 b)

Description: The fungal spores are spherical, composed of four cells, measuring 40 x 30 µm, with a central opening and thin edges, and they are smaller than the other cells. Septa are thin structures, measuring 2-4 µm in thickness, that can be either curved or straight. Smooth connection with the spore wall, with a thickness of 1 µm and possess a smooth surface.

Age: Early Eocene

Occurrence: Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation

Species: *Pluricellaesporites planus* Kalgutkar and Jansonius, 2000

(Plate 7.6 c)

Description: Fungal spores with multiple cells, with the upper cells being larger and the bottom ones being smaller. Size: 25-30 μm . Smooth walls, less than 1 μm diameter, and are black in color (Kalgutkar and Jansonius, 2000).

Age: Eocene

Occurrence: Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation

Family: Dictyosporae

Genus: *Polycellaesporonites* (Chandra, Saxena and Setty, 1984)

Species: *Polycellaesporonites bellus* Chandra, Saxena and Setty, 1984

(Plate 7.6 d)

Description: The fungal spores are enclosed in a capsule and lack any openings. One end of the spore is rounded while the other end has a tube-like protrusion. The spores are composed of several cells that are clustered together, rather than arranged in a linear or single-axis pattern. The surface of the spore wall is smooth. The spore is enclosed in a capsule and has a tube-like protrusion at one end. It is composed of several cells and lacks an opening. The cells are crowded together, and the spore wall can vary in texture from smooth to ornamented. Size is 10-15 μm .

Age: Early Paleocene- Late Quaternary

Occurrence: Ninama Limestone

Species: *Polycellaesporonites psilatus* Gupta, 2002

(Plate 7.6 e-f)

Description: The spores are elongated, consisting of many cells, without apertures, measuring 10-15 μm in length, and arranged in clusters of up to 3 or more cells. The surface of the spores is smooth and folded.

Age: Eocene

Occurrence: Chotila Chert, Bamanbor Formation

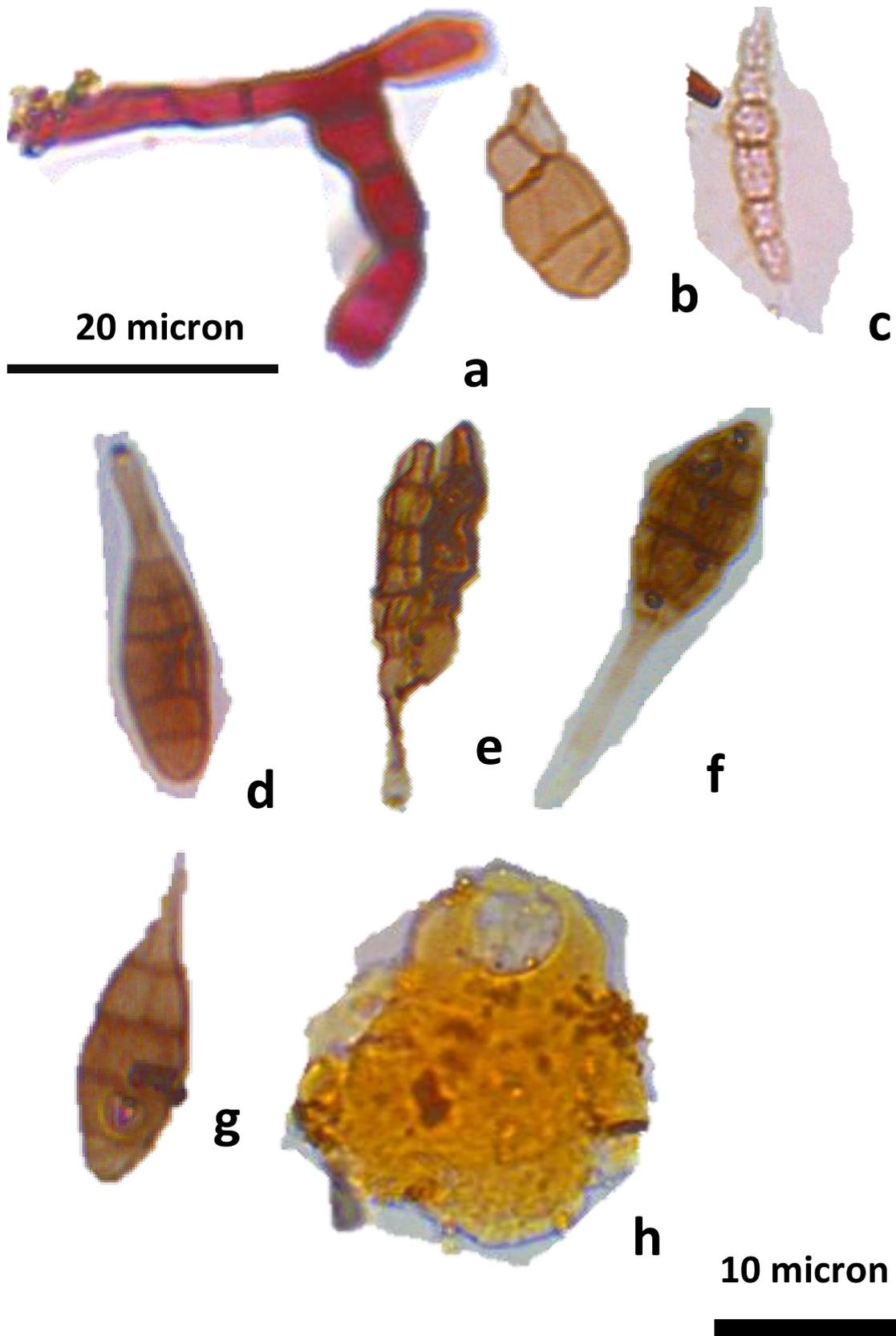


Plate 7.6 a. *Ceratohirudispora triradiata*, SF-NB, b. *Plureicellaesporites globatus*, BF-CB, c. *Plureicellaesporites planus*, BF-CB, d. *Polycellaesporonites bellus*, NL-NB, e-f. *Polycellaesporonites psilatus* CC-CB, g. *Polycellaesporonites saxenae*, BF-CB, h. *Staphlosporonites settyi* CC-CB.

Species: *Polycellaesporonites saxenae* Gupta, 2002

(Plate 7.6 g)

Description: Spores are elongated and multicellular, with cells organized in clusters along many axes at one end and a tube-shaped appendage at the other. It is inaperturate, having a length of 15-20 μm and a breadth spanning three or more cells. The spores have a granular texture, characterized by well-defined sculptural features in the cell clusters but less defined in the appendage. The spores possess a folded surface.

Age: Eocene

Occurrence: Chotila Chert, Bamanbor Formation

Genus: *Staphlosporonites* Kalgutkar and Jansonius 2000

Species: *Staphlosporonites settyi* Gupta, 2002

(Plate 7.6 h)

Description: The spores are composed of many cells and have a round shape without any openings. They have a nearly round appearance and measure 15×20 or $20 \times 20 \mu\text{m}$. The cells have diverse morphologies and are positioned in an uneven manner, forming multiple layers over the whole thickness. The septa exhibit a range of thickness, spanning from slender to as substantial as the wall. The spores have a mostly smooth surface, with little creases or folds.

Age: Eocene

Occurrence: Chotila Chert

Family- Staurosporae

Genus: *Frasnacritetrus* Taugourdeau, 1968

Species: *Frasnacritetrus indicus* Saxena and Khare, 1992

(Plate 7.7 a)

Description: The fungal conidia has four appendages. The primary structure is a rectangular shape that is extended, with a length ranging from 15 to 25 μm . It is composed of several cells and is divided by ridges and furrows that extend in both longitudinal and transverse directions. The spore wall has a maximum thickness of 1 μm and is composed of conate structures that are equally distributed. The processes are segmented, with a length ranging from 15 to 50 μm and a width of 2 to 3 μm . Each process is characterized by having 2-5 septa and a smooth surface.

Age: Eocene

Occurrence: Ninama Limestone, Rangpar Formation, Chotila Chert

Species: *Frasnacritetrus taugourdeau* Saxena and Sarkar, 1986

(Plate 7.7 b)

Description: The fungal conidia has four protrusions. The main body is biconvex, spindle-shaped, and consists of a single cell. The surface is granulose, with minute grana that are tightly spaced and equally dispersed. The body produces processes that are tubular and somewhat broader at the base. All processes have a uniform shape and a smooth wall. Some processes include septa in their basal section. The length of the object is between 40 and 50 micrometers, whereas the size of the processes is 30 μm .

Age: Eocene

Occurrence: Rangpar Formation, Chotila Chert

Family- Didymosporae

Genus: *Fusiformisporites* Rouse, 1962

Species: *Fusiformisporites* sp. Rouse, 1962

(Plate 7.7 c)

Description: The fungal spores are dicellate and lack an aperture. They have elongated striae, ribs, ridges, or costae that are aligned parallel to the long axis of the spore. Structure composed of one or several layers. The inner surface of the wall is characterized by a texture that is either smooth with little bumps or rough and scaly. The equatorial septum consists of two layers. The presence of equatorial constriction of the wall is observed.

Age: Paleocene-Eocene?

Occurrence: Ninama Limestone

Genus: *Papulosporites* Schmiedeknecht and Schwab, 1964

Species: *Papulosporonites multicellatus* Kalgutkar and Jansonius, 2000

(Plate 7.7 d-e)

Description: The fungal spores are round to subcircular, with a size range of 40 \times 60 μm . Multicellular, with more than 25 cells in each spore. Each individual cell has a polygonal form

and is around 5-8 μm in size. Unperforated. Septa are thin. The spore wall has a maximum thickness of 2 μm and is covered with little bumps.

Age: Paleocene-Pliocene

Occurrence: Ninama Limestone, Chotila Chert, Bamanbor Formation



Plate 7.7, a. *Frasnacritetrus indicus*, CC-CB, b. *Frasnacritetrus taugourdeau*, CC-CB, c. *Fusiformisporites* sp., NL-NB, d-e. *Papulosporonites multicellatus*, d, NL-NB, e- BF-CB, and f. *Dicellaesporites minutus*, BF-CB.

Genus- *Dicellaesporites* Elsik 1968

Species: *Dicellaesporites minutus* Kar and Saxena, 1976

(Plate 7.7 f)

Description: The spores are bicellate, with obvious septa. They are oval in form and measure 20 x 15 μm . The spores are inaperturate and the septa are clearly visible. The individual cells

inside the spores are approximately the same size and shape. Spore wall up to 1 μm thick, laevigate.

Age: Paleocene

Occurrence: Bamanbor Formation

Family- Amerosporae

Genus: *Inapertisporites* van der Hammen, 1954

Species: *Inapertisporites kedvessi* Elsik, 1968

(Plate 7.8 a-b)

Description: The grains are round, smooth, and lack openings, with a size ranging from 60 to 80 μm . The wall has a thickness of 0.2 μm . Typically exhibits several folds.

Age: Paleocene

Occurrence: Sukhbhadar Formation, Ninama Limestone, Chotila Chert

Species: *Inapertisporites maximus* Kalgutkar and Jansonius, 2000

(Plate 7.8 c-d)

Description: The spores have a subcircular to elliptical form, which appears uneven owing to folding. They are composed of a single cell and are psilate. The spore wall can be up to 1 μm thick and has a smooth surface with random folds.

Age: Miocene-Pleistocene

Occurrence: Sukhbhadar Formation, Ninama Limestone, Chotila Chert, Bamanbor Formation

Species: *Inapertisporites novus* Gupta, 2002

(Plate 7.8 e)

Description: The spores are single-celled, without septa, inaperturate, and have a shape that ranges from almost round to nearly circular. Punctate and a folded appearance, with a wall thickness of up to 1 μm .

Age: Early Eocene

Occurrence: Bamanbor Formation

Age: Paleogene - Neogene

Occurrence: Sukhbhadar Formation, Ninama Limestone, Chotila Chert, Bamanbor Formation

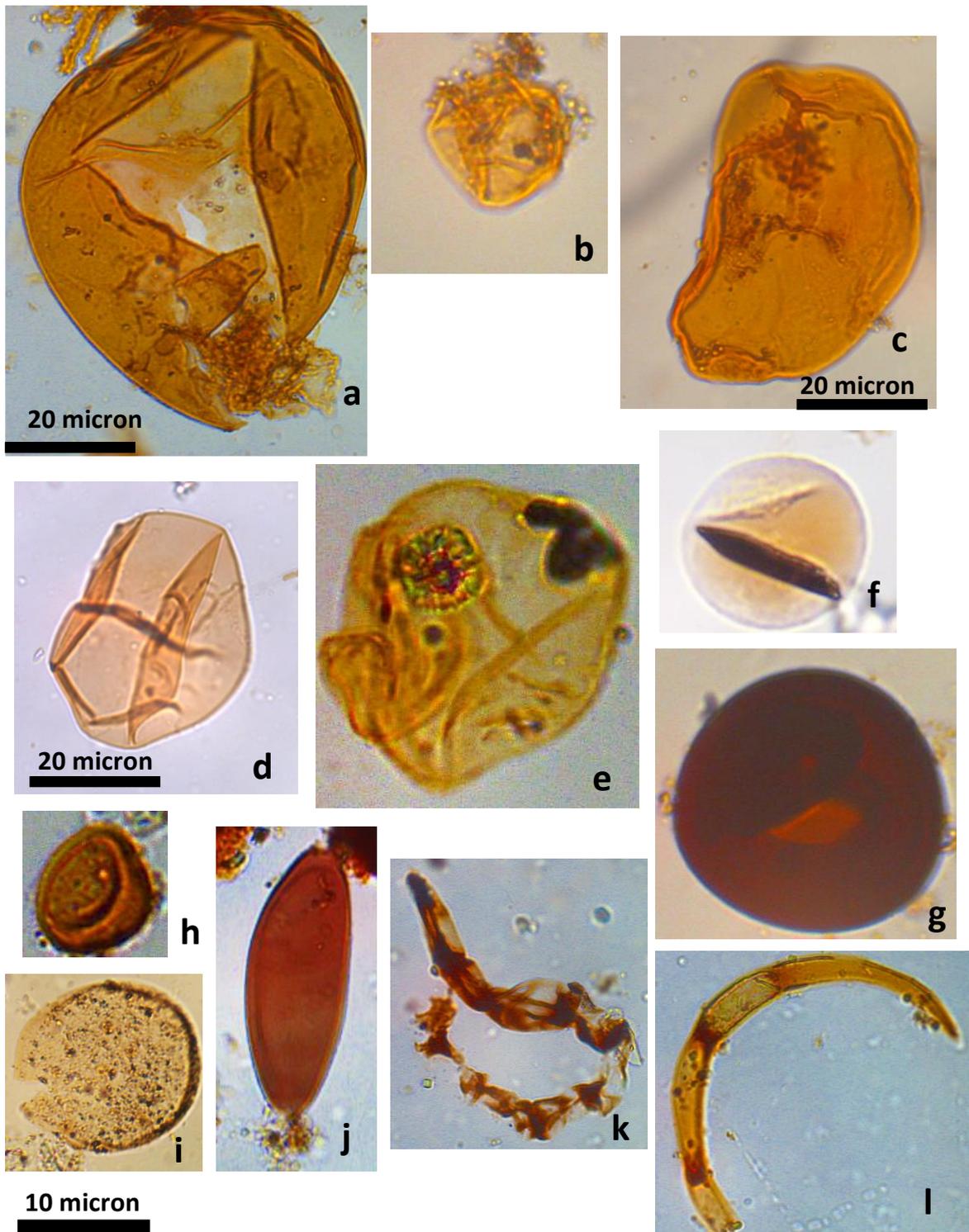


Plate 7.8 a-b. *Inapertisporites kedvessi*, a, SF-NB, b, NL-NB, c-d, *Inapertisporites maximus*, NL-NB, e. *Inapertisporites novus*, BF-CB, f-g. *Hypoxylonites subrotundus*, NL-NB, h. *Hypoxylonites minimus*, BF-CB, i. *Monoporisporites circularis*, NL-NB, j. *Diporisporites sirmaurensis*, CC-CB, k-l *Helicominites salvinites*, CC-CB.

Species: *Hypoxylonites minimus* Nandi, Banerjee and Sinha 2003

(Plate 7.8 h)

Description: The spores are elliptical in shape, with convex sides and a rounded apex. There is a lengthy furrow that crosses one end of the spore and almost encircles it along its polar axis. The spore exine is thick, but becomes thinner around the aperture, and the surface is smooth. The spore size varies between 5 to 20 μm .

Age: Tertiary

Occurrence: Rangpar Formation, Bamanbor Formation

Genus- *Monoporisorites* Kalgutkar and Jansonius 2000

Species: *Monoporisorites circularis* Saxena, 2009

(Plate 7.8 i)

Description: The spores are round, with a diameter of 40-50 μm . They are opaque and are monoporate, with pore centrally located. The pore wall is thick and uniform, with a diameter of about 6 μm . The spore wall is smooth.

Age: Early Eocene

Occurrence: Ninama Limestone

Genus: *Diporisorites* van der Hammen, 1954

Species: *Diporisorites sirmaurensis* Gupta 2002

(Plate 7.8 j)

Description: The fungal spores are single-celled, without septa, porate and round in shape. They measure 10-15 μm and have pores located at opposite ends. The spores have a basic structure, psilate smooth surface and a wall that is 1 μm thick.

Age: Eocene

Occurrence: Chotila Chert

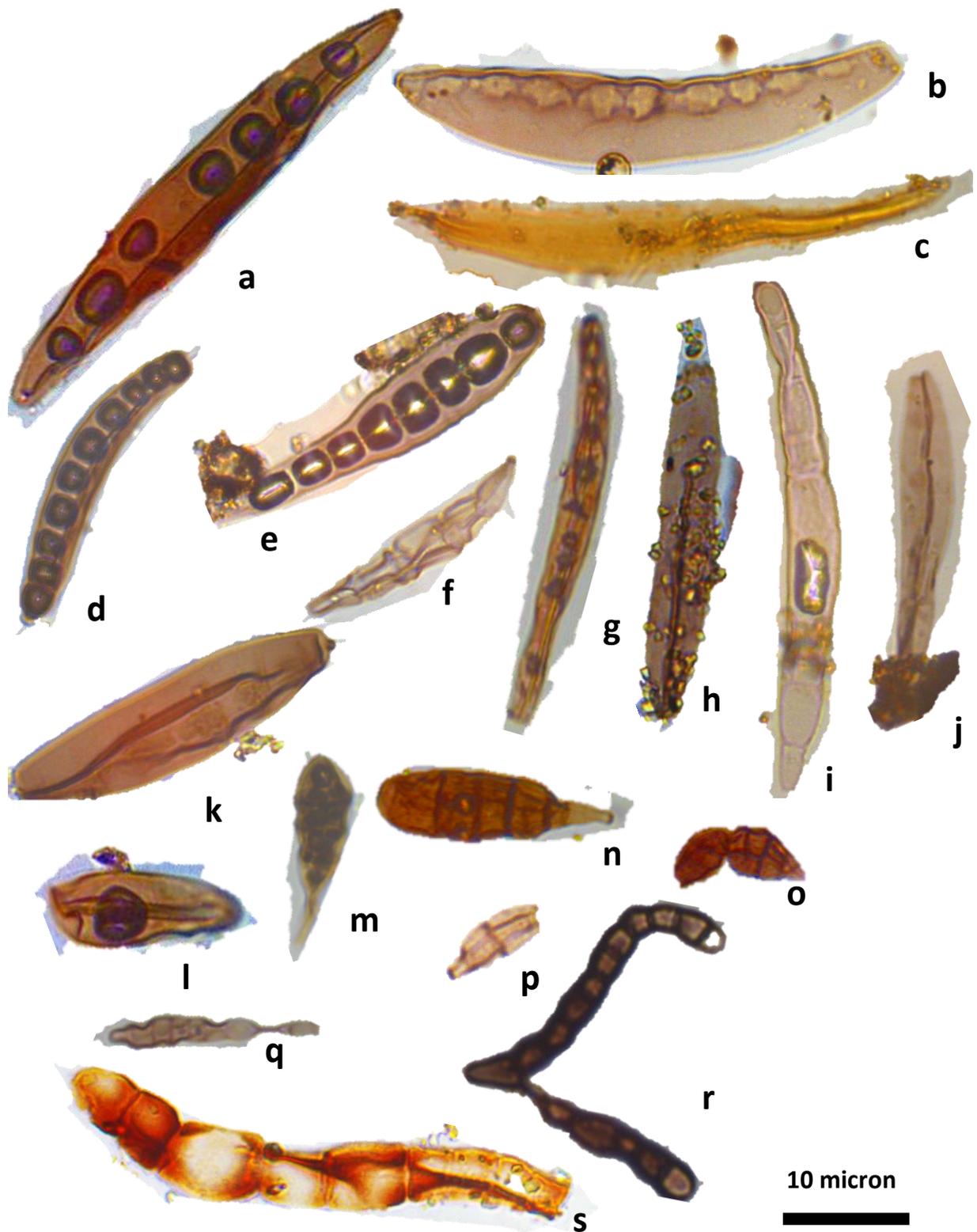


Plate 7.9, a-g, *Polycellaesporonites* spp., a-c, NL-NB, d-f, CC-CB, g, BF-CB, h-l *Diporisporites sirmaurensis*, CC-CB, m-q, *Pluricellaesporites* spp., m-o, CC-CB, p-q, BF-CB, r. *Ceratohirudispora* sp. BF-CB, s. *Helicominits* sp. CC-CB.

Family: Helicosporae

Genus: *Helicominites* Barlinge and Paradkar, 1982

Species: *Helicominites salvinites* Barlinge and Paradkar, 1982

(Plate 7.8 k-l)

Description: The fungus is saprophytic and has a mycelium that is 4-5 μm wide. The conidia are loosely coiled in a spiral shape and have a size of 30-40 μm , with thin ends.

Age: Cretaceous-Maastrichtian

Occurrence: Chotila Chert

Phylum- Mucoromycota

Order- Endogonales

Genus: *Palaeomycites* Kalgutkar and Jansonius, 2000

Species: *Palaeomycites* spp. Kalgutkar and Jansonius, 2000

(Plate 7.10 a)

Description: The mycelium consists of branched and intertwined hyphae, without septa. The hyphae often end in large round or oval sporangia, which may or may not contain spores. The sporangia can be found individually or in clusters. Sporangia developed as a swelling within a hypha.

Occurrence: Sukhbhadar Formation, Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation

Species: *Palaeomycites acinus* Kalgutkar and Jansonius, 2000

(Plate 7.10 b)

Description: The mycelia exhibit subdichotomous branching, with numerous unilateral projections that are convoluted and aseptate. The mycelia have a uniform thickness, except at the base of vesicles and branching areas, where the thickness is greater. The diameter of the mycelia is 4-8 μm . The mycelia wall is smooth, hyaline, and single-layered, with an irregular thickness, being thicker at the base of vesicles and branching areas. The vesicles are round or slightly oval in shape, and they are typically darker than the mycelia.

Age: Maastrichtian

Occurrence: Sukhbhadar Formation, Ninama Limestone, Rangpar Formation, Chotila Chert, Bamanbor Formation.

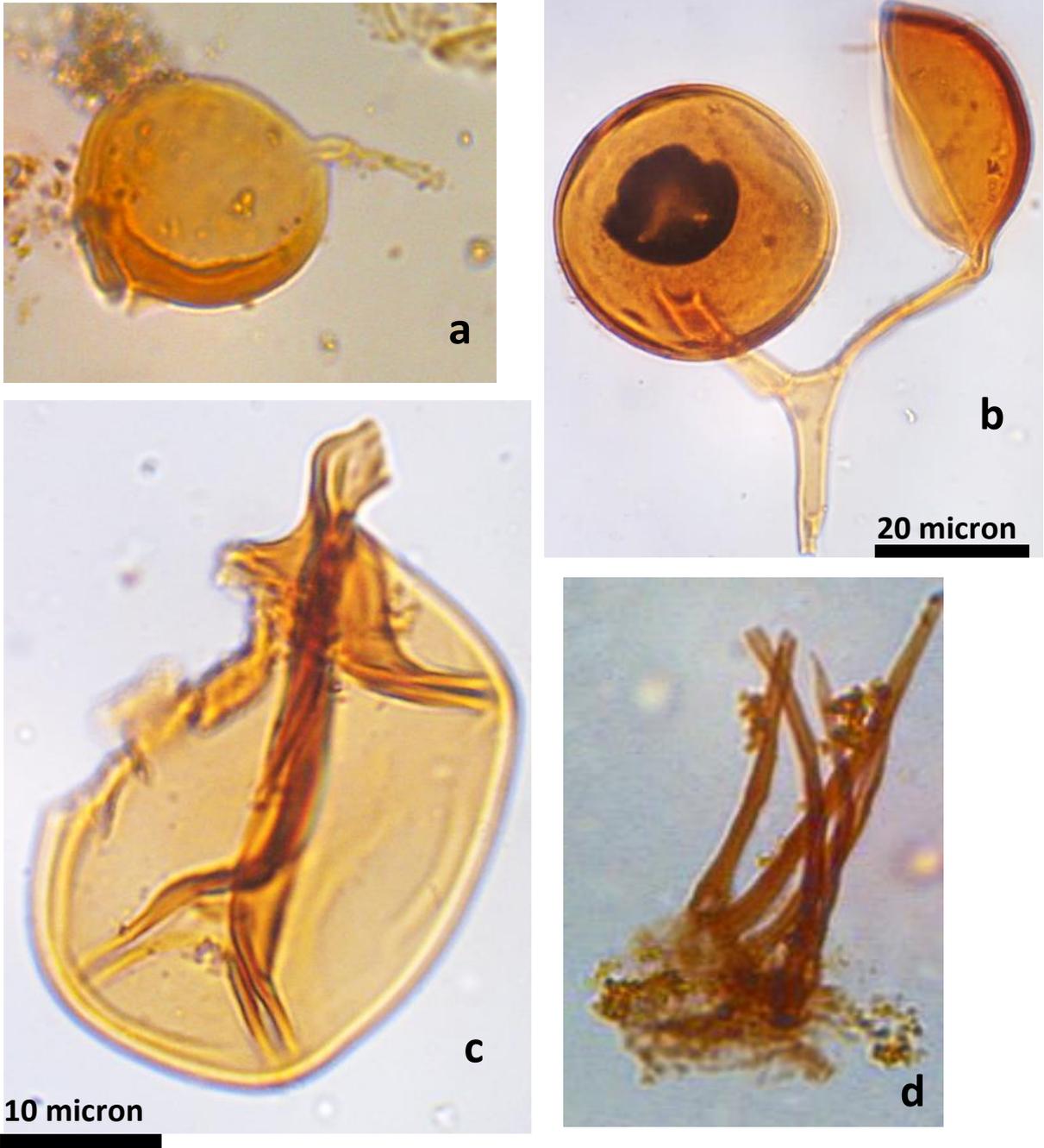


Plate 7.10, a. *Palaeomycites* spp., NL-NB, b. *Palaeomycites acinus*, NL-NB, c. *Udaria saxenae*, SF-NB, d. *Protocolletotrichum deccanensis*.

Genus: *Udaria* Gupta, 1996

Species: *Udaria saxenae* Gupta, 1996

(Plate 7.10 c)

Description: The object is light brown in color and has a subcircular to ellipsoidal shape. It is characterized by a slit and a tube-like appendage. The size of the object is between 60 and 110 micrometers, with a wall thickness of up to 7 micrometers. The surface is folded in an uneven manner and has a smooth texture. The appendage is 3 to 8 μm .

Age: Early Tertiary

Occurrence: Sukhbhadar Formation, Ninama Limestone

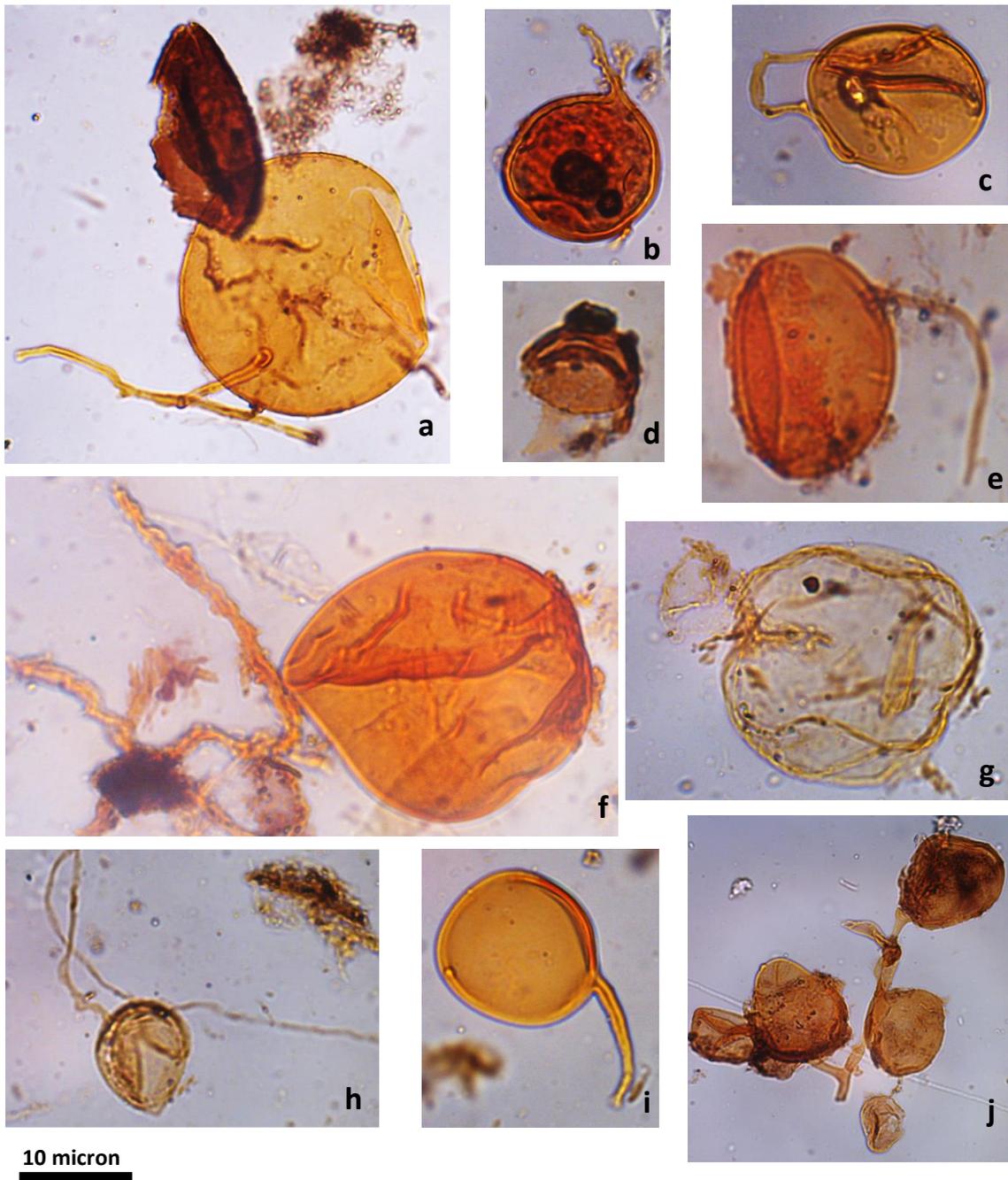


Plate 7.11 a-j *Palaeomycites* sp., a-c, SB-NB, d-f, NL-NB, g-j- RF-CB.

Order- Deuteromycetes

Family- Melanconiaceae

Genus: *Protocolletotrichum* Kar, Sharma and Kar 2004

Species: *Protocolletotrichum deccanensis* Kar, Sharma and Kar 2004

(Plate 7.10 d)

Description: Approximately more than 15 randomly positioned acervuli on a cuticle fragment measuring up to 80-90 μm length and 0.1 cm in width, which does not display any cellular or stomatal characteristics. The acervulus is surrounded by 20-35 setae that emerge from its edges. These setae are straight and somewhat spread out, with wide bases and sharp points or damaged tips. The setae have cell walls that are approximately 2 μm thick and have a psilate texture.

Age: Maastrichtian

Occurrence: Bamanbor Formation

7.3.3 Testate Amoeba

Arcellinidans, or testate lobose amoebae, are a group of protists that belong to the Order Arcellinida. The extracted arcellinidans are represented by *Centropyxis aculeata* and *Arcella arenaria* were recorded from both the basins.

Kingdom Protista

Phylum: Amoebozoa Corliss, 1984

Subphylum: Lobosa Carpenter, 1861

Class: Tubuliniea Smirnov, Nassonova, Berney, Fahrni, Bolivar and Pawlowski, 2005

Subclass: Testacealobosia De Saedeleer, 1934

Order: Arcellinida Kent, 1880

Suborder: Arcellinina Haeckel, 1884

Superfamily: Diffflugacea Stein, 1859

Family: Centropyxidae Jung, 1942

Genus: *Centropyxis* Stein, 1857

Species: *Centropyxis aculeata* Ehrenberg, 1832

(Plate 7.12 a-c)

Description: The test is bilaterally symmetrical, with an outline that is subcircular to ovoid. The shell is made up of a proteinaceous matrix that contains agglutinated mineral grains and diatom frustules. The aperture is either sub-terminal or eccentric, and it is invaginated, with numerous spines. Currently, there are some undamaged spines, but a significant number are frequently fractured. The number of spines can range from two to five or even more, and their size can vary between 60 µm to 75 µm. There are typically five to eight conical spines that are laterally oriented. These spines are generally straight, but they may occasionally be twisted, and their length can vary. Spines protrude from various locations along the edge of the shell or from half of its perimeter (Farooqui et. al. 2012).

Age: Permian-Quaternary

Occurrence: Ninama Limestone, Sukhbhadar Formation, Bamanbor Formation, Chotila Chert and Rangpar Formation

Family: Arcellidae Ehrenberg, 1843

Genus: *Arcella* Ehrenberg, 1832

Species: *Arcella arenaria* Greeff, 1866

(Plate 7.12 d-f)

Description: The apical view of *Arcella arenaria* consistently displays a round shell. No distinct border or bosses are present along the lateral margin of the shell or the margin of the aperture. The opening is little, round, with a diameter that scarcely surpasses 1/5 of the shell size. The surface of the aperture is typically smooth, occasionally marked with pits, and may exhibit either sparse or dense perforations. The fossil shell has a circular form when viewed from the top, with a diameter ranging from 50 µm to 80 µm. The dorsal view is often compressed with subtle creases. The opening is diminutive, round, and centrally located, encircled by a few minuscule pores. The tiny pores have a mostly round or somewhat elongated morphology. The diameter of the aperture is 18–21 µm, which is only around 1/5–1/6 of the diameter of the shell. The outer side of the shell has mamillated or pitted texture. The shell diameter to shell aperture ratio varies between 3.6 and 5.1. The existing forms of these are morphometrically related, with shell sizes ranging from 71–103 µm and aperture diameters ranging from 15–26 µm. The shell diameter to shell aperture ratio varies between 3.8 and 4.8. The mean ratio of shell diameter to aperture diameter in both fossil and modern specimens is 4.5 and 4.3, respectively (Farooqui et al., 2012).

Measurements: The shell diameter is 60–97 μm ; the aperture is 10–28 μm . *Arcella arenaria* is distinguished by a smaller ratio of aperture diameter to shell diameter.

Age: Permian-Quaternary

Occurrence: Ninama Limestone, Sukhbhadar Formation, Bamanbor Formation, Chotila Chert and Rangpar Formation

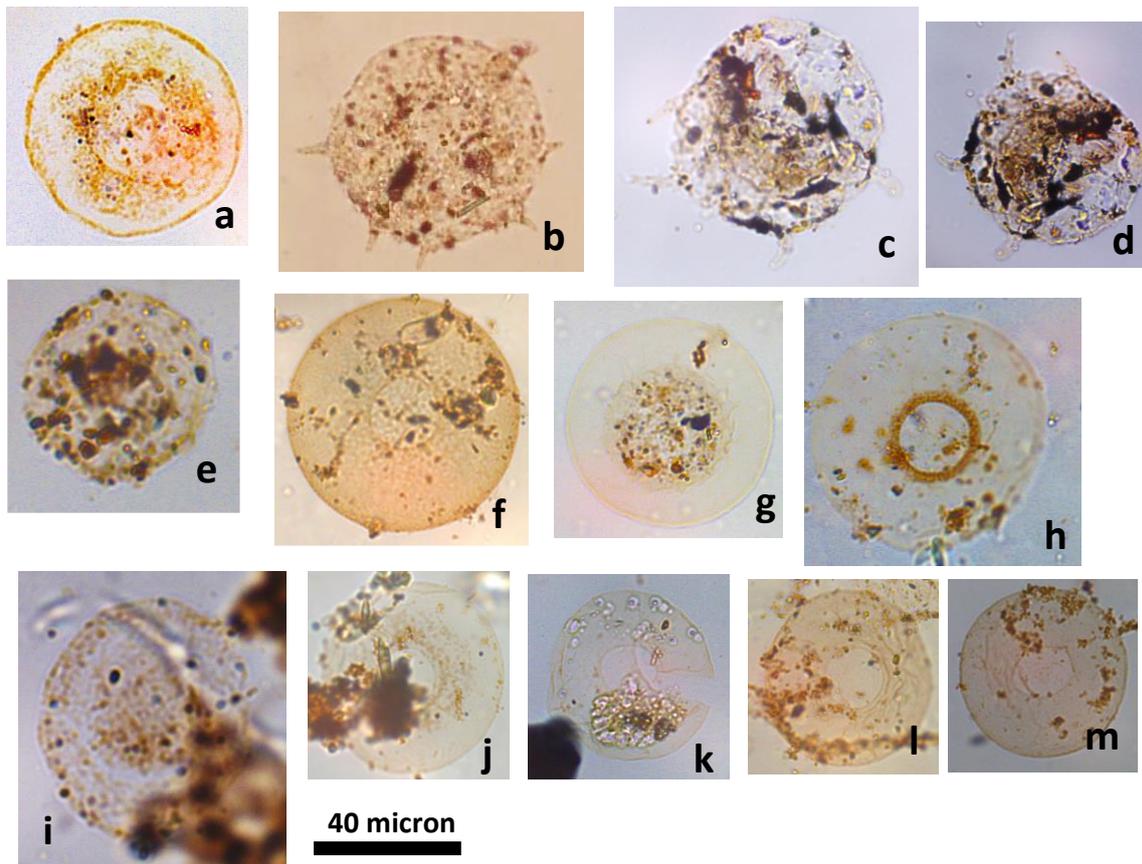


Plate 7.12, a-f, *Centropyxis aculeata*, a-c- NL-NB, d-f, RF-CB, g-m, *Arcella arenaria*, g-j- RF-CB, k-m, BF-CB.

7.3.4 Phytoplankton

Genus: *Botryococcus* Kützing, 1849

Species: *Botryococcus braunii* Kützing, 1849

(Plate 7.13 a-b)

Description: Colonies of the fossil alga appear irregularly spherical to oval in shape with radially arranged cells which are 3–5 μm in diameter and distally opened. The cups are sometimes hollow exhibiting pore like structures. The ovoid cup shaped structures arranged in

quadrangular or circular pattern. Size of individual alga 60–70 μm and colonies range in size from 150–300 μm .

Affinity: Botryococcaceae

Age: Permian to Quaternary

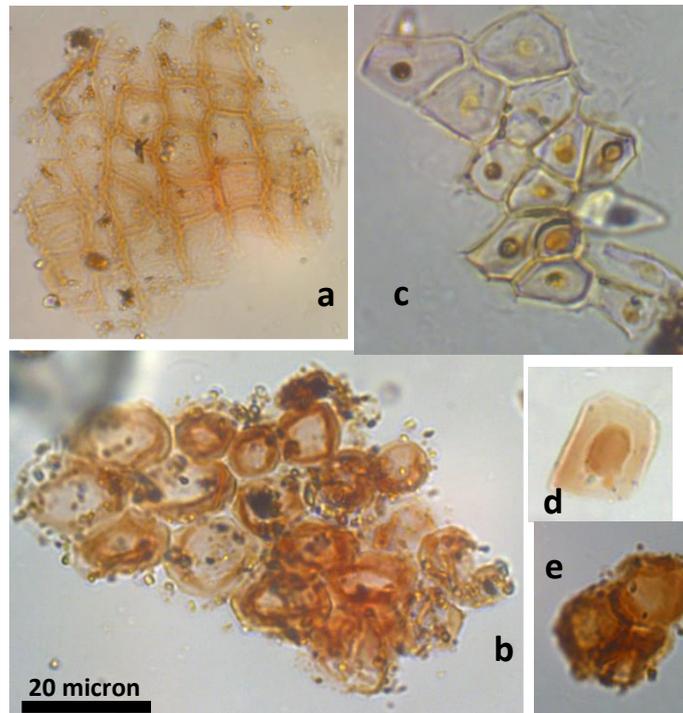


Plate 7.13 a. *Botryococcus braunii*, BF-CB, b. NL-NB, c-e, *Pediastrum* sp. NL-NB.

Division- Chlorophyta

Class- Chlorophyceae

Order- Chlorococcales

Family- Hydrodictyaceae

Genus: *Pediastrum* Meyen, 1829

(Plate 7.13 c-e)

Description: Colonial alga, coenobium a double layered plate having inner coenocytes as well as marginal coenocytes. Coenocytes arranged in compact rings, number of rings indeterminable, perforations absent. Marginal coenocytes 10-15 or more in number, triangular, rhombohedral in shape. Inner coenocytes numerous, and broken.

Age: Triassic- Recent

Occurrence: Ninama Limestone, Bamanbor Formation

Dinoflagellates

The Ninama and Chotila Basin are rather deficient of dinoflagellates with few rare sporadic occurrences in ML facies of Ninama Limestone, Ninama Basin.

7.3.5 Rotifers

Rotifers, minute, usually microscopic but many-celled, flask-shaped bodies, single or in chains with thick tubular wall forms. They are mainly freshwater aquatic invertebrates having the anterior end modified into a retractile disk bearing circles of strong cilia that often give the appearance of rapidly revolving wheels. Their size ranges from 50 to 100 μm and they are made up of pseudochitin (Plate 7.14a) (Limaye et al., 2007; El Atfy et al., 2023).

7.3.6 Arthropod remains

Cladocerans, or water fleas, carapaces and appendages (antennae, antennules, mandibles, post-abdominal claws, etc.) are also observed. They are generally disarticulated in nature and highly fragmented (Plate 7.14 b-d).

Lepidopteran scales were also observed from both the basins. Morphologically, the apical margins of the scales were rounded as well as serrated, dense cross ridges were observed with microribs, structure was solid with rare perforations. The size of the scales varies from 20-30 μm to 80-90 μm (Plate 7.15 a-f) (Van Eldijk et al., 2018).

7.3.7 Phytoclasts (Structural terrestrial organic matter)

The organic matter like root, stem tissues and cellular remains like cuticles, tracheid, and wood are encountered in the sediments of both the basins. It represents about 5% of the palynomorphs. The presence of structured wood is very common with size of 10-80 μm (Plate 7.14e-h).

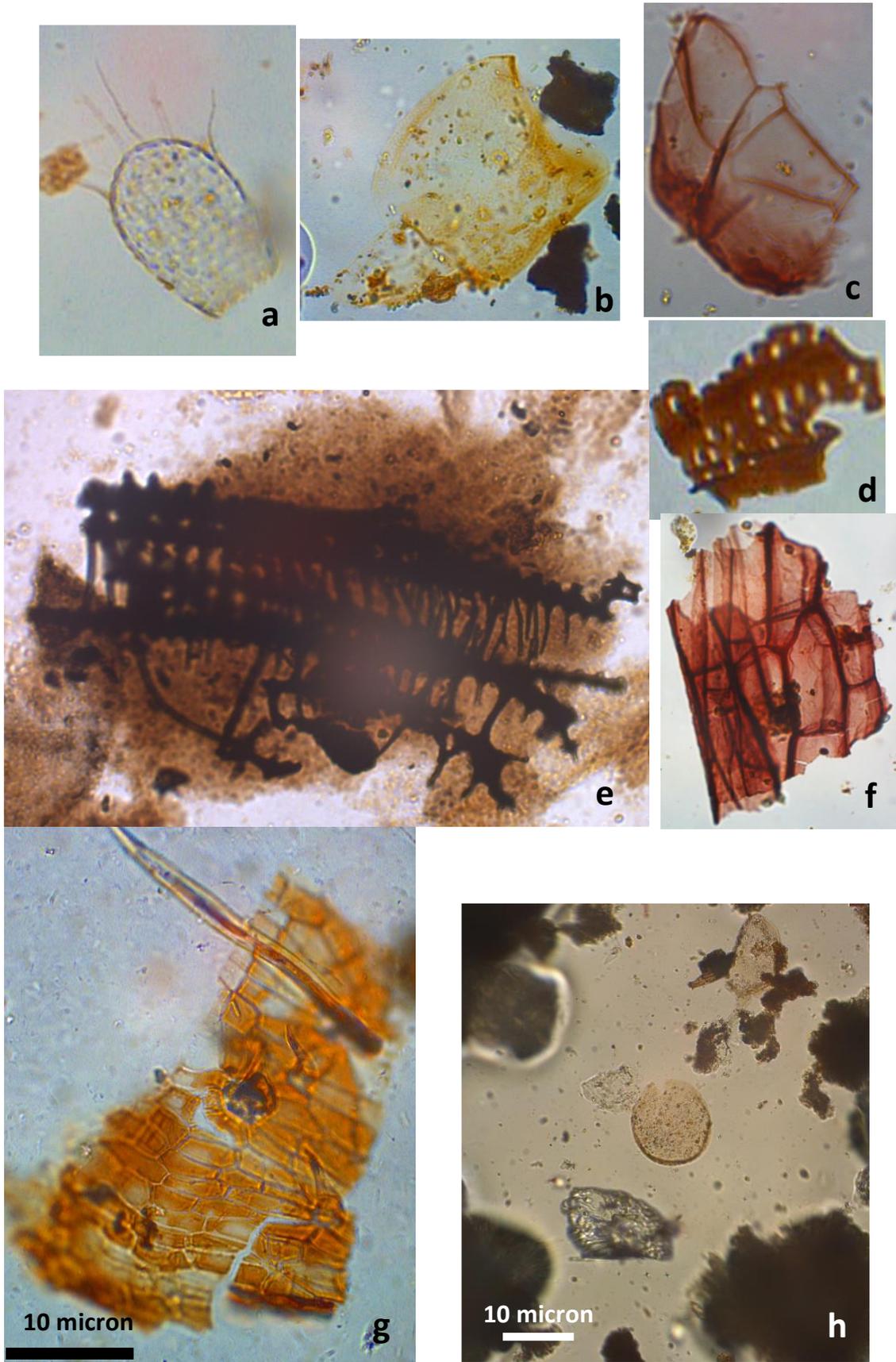


Plate 7.14 a. Rotifer, CC-CB, b-d, Cladocera, NL-NB, e-h, Phytoclast e-f, NL-NB, g. RF-CB, h. BF-CB, i- AOM..

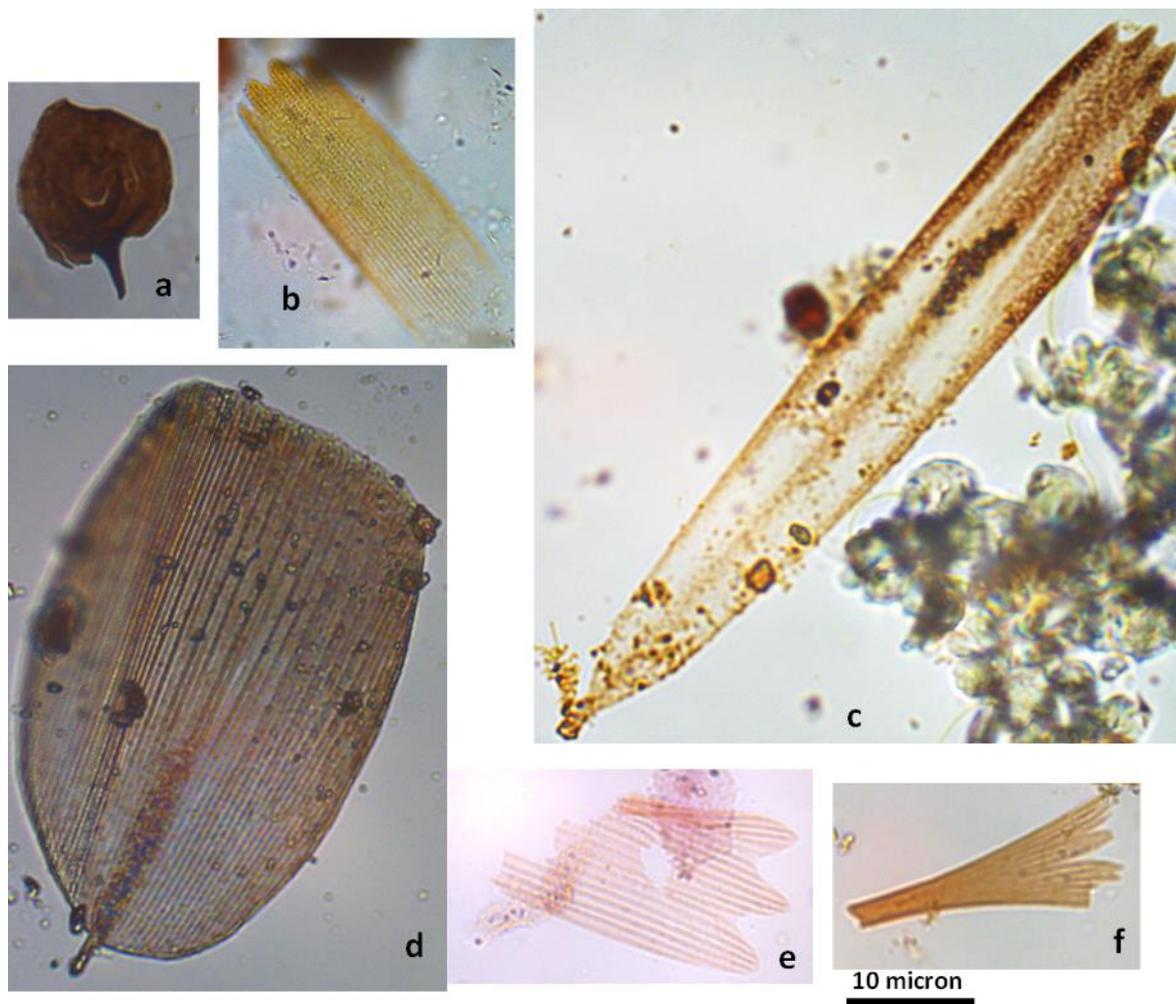


Plate 7.15 a-f, Lepidopteran Scales, a-d, NL-NB, e-f, CC-CB.

7.3.8 Amorphous Organic Matter (AOM)

The Amorphous Organic Matter (AOM) is most abundant type of organic matter found in the samples of Ninama and Chotila Basin. The percentage of the AOM varies from 10-20 to >80%. It appears structureless, can be granular or flaky and is irregular in form. The colour varies from yellow to brown and grey. The size of AOM ranges from 2-3 μ m to 40-50 μ m. The dominance of AOM is due to high amount of preservation in low energy environment. The dark grey to black colour is also evident of an anoxic environment (Masran and Pocock, 1981, Tyson, 1993).