Spore-Pollen Biostratigraphy and Paleoecology of Mesozoic and Lower Tertiary Samples from the Surghar and Salt Ranges, Northern Pakistan

By N.O. Frederiksen, U.S. Geological Survey
T.P. Sheehan, U.S. Geological Survey
V.A.S. Andrle, U.S. Geological Survey

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Abstract

The conglomerate at the base of the Basharat drill hole 34 (eastern Salt Range), thought to represent the Tobra Formation (Permian), contained Permian pollen grains and spores that may be indigenous or may be reworked; thus, the age of this conglomerate is uncertain.

Two samples from the lower part of Lumshiwal Nala (Makarwal coal field, Surghar Range), probably from the Lumshiwal Formation, were assigned Late Jurassic to Early Cretaceous and middle Cretaceous (approximately Aptian to Albian) ages, respectively.

Rocks from the shallow subsurface of the Kuraddi section in the western Salt Range, thought to be possibly from the Paleocene Hangu Formation, contained spores and pollen grains probably of Jurassic to Early Cretaceous age; therefore, these samples were probably from the Mesozoic Datta Formation.

Rocks mapped as the Hangu Formation at Lumshiwal Nala (Surghar Range) and Nammal Pass (western Salt Range) are Paleocene in age. All analyzed samples of the Patala Formation from the Salt Range appear to be late Paleocene in age and contain pollen assemblages similar to those of the Lakhra Formation of Sindh Province. The Patala assemblages are no older than those from the uppermost part of the Bara Formation of Sindh Province. Paleocene coal beds in the Hangu and Patala Formations were undoubtedly deposited in or near brackish water because dinoflagellate cysts and brackish-water palm pollen of the genus *Spinizonocolpites* were found in the associated detrital rocks.

Two samples from the Nammal Formation (lower Eocene(?)) of the Basharat drill hole 34 (eastern Salt Range) had low-diversity spore and pollen assemblages that did not include any species known to be restricted to the Eocene, although some new species were present that might be so restricted.

Introduction

Lower and middle Eocene rocks of the Surghar and Salt Ranges (figs. D1, D2) were deposited entirely in marine environments and can generally be given an age assignment using marine megafossils or microfossils. However, some of the Mesozoic and Paleocene formations of the region are predominantly nonmarine; although marine fossils have been found in these formations in certain areas, many outcrops lack such fossils. Spores and pollen are therefore most useful in providing ages and correlations of mainly nonmarine units. Previously published Tertiary spore and pollen work in the region includes a description of some late Paleocene or Eocene species from Dandot, in Jhelum District, Punjab, by Vimal (1952) and a description of many Paleocene species from northern and southern Pakistan by Frederiksen (1994).

In the present study of spores and pollen from the Surghar and Salt Ranges, 1 sample was analyzed from the Tobra Formation(?) (Permian(?)), 2 from the Lumshiwal Formation (Mesozoic), 7 from rocks thought at least tentatively to represent the Hangu Formation (Paleocene), 26 from the Patala Formation (mainly or entirely Paleocene), and 2 from the Nammal Formation (Eocene(?)). Spore-pollen species mentioned in the text and figures are listed in appendix D1. Many taxa studied are shown in plates D1–D4.

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Previously Reported Ages of Formations

The Lumshiwal Formation of the Surghar Range (table D1) contains very few marine fossils but was thought by Fatmi

Figure D1. Location map showing the Salt Range study area (box) and selected regional features.

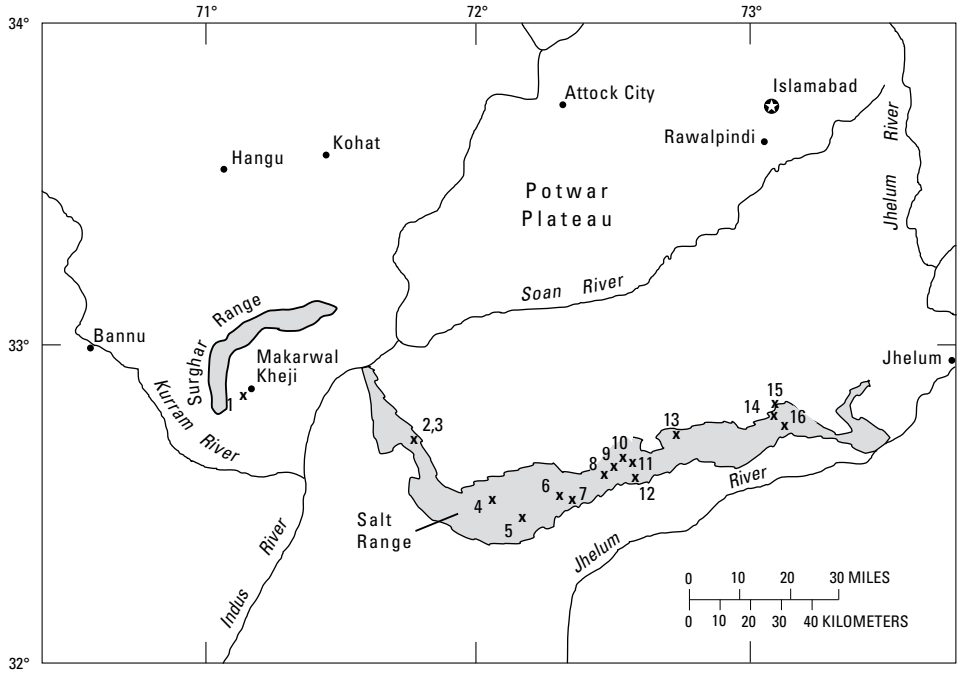

Figure D2. Map of the Salt Range study area in northern Pakistan showing sample localities discussed in this report. 1, Lumshiwal Nala; 2, Nammal Pass section; 3, Nammal Dam section; 4, Kuraddi section; 5, sample R4264; 6, sample R4262; 7, Arara section; 8, sample R4242M; 9, sample R4242K; 10, sample R4242J; 11, Nila Wahan section; 12, sample R4242L; 13, drill hole 9 in Khairpur area; 14, drill hole 34 in Basharat area; 15, sample R4242E; and 16, sample R4242D.

Table D1. Some stratigraphic units in Sindh Province and in the Surghar and Salt Ranges, Pakistan.

[No stratigraphic correlations between units in the two regions are implied]

Sindh Province	Surghar and Salt Ranges
Tertiary—Paleocene and Eocene	Tertiary—Paleocene and Eocene
Laki Formation	Nammal Formation
Ranikot Group	Patala Formation
Sohnari Formation	Lockhart Limestone
Lakhra Formation	Hangu Formation
Bara Formation	Jurassic and Cretaceous
Khadro Formation	Lumshiwal Formation
	Chichali Formation
	Samana Suk Formation
	Datta Formation

(1972, p. 323) to be probably Aptian(?) to middle Albian in that region. In other areas the Lumshiwal Formation is thought to contain strata ranging from Upper Jurassic to Albian (Fatmi, 1972), but in general, the age of the formation and the ages of different levels within the formation are poorly known.

The Hangu Formation and its presumed correlative, the Dhak Pass Formation, contain foraminifers in some areas of the Salt and Surghar Ranges, and these fossils have suggested an early Paleocene age (Cheema and others, 1977). Most samples from the Hangu and Dhak Pass Formations examined for calcareous nannofossils and dinoflagellates by Köthe (1988) were barren of these fossils, but several samples contained sparse calcareous nannofossil and dinoflagellate assemblages that were assigned to the upper Paleocene by these authors. L.E. Edwards (this volume, chap. C) assigned rare dinoflagellates from two samples probably of the Hangu Formation at Nammal Pass (fig. D2, locality (loc.) 2) provisionally to the upper Paleocene. In summary, (1) the Hangu and Dhak Pass Formations appear to contain mainly nonmarine strata (or at least it has been difficult to obtain marine fossils from these formations), and therefore the ages of the formations are not well known in many areas; and (2) no effort seems to have been made to reconcile early Paleocene ages for the Hangu and Dhak Pass Formations based on foraminifers with late Paleocene ages based on dinoflagellates and calcareous nannofossils. Ages of coal beds in the Hangu and Dhak Pass are poorly known on the basis of marine fossils.

The Patala Formation is considered to be upper Paleocene in most areas but extending into the lower Eocene in a few places, on the basis of mollusks, foraminifers, ostracodes, calcareous nannofossils, and dinoflagellates (Cheema and others, 1977; Köthe, 1988). According to L.M. Bybell and J.M. Self-Trail, L.E. Edwards, and T.G. Gibson (this volume, chaps. B, C, and E), the uppermost part of the Patala at Nammal Dam (general area of fig. D2, locs. 2, 3) is uppermost Paleocene. Furthermore, the Lockhart Limestone, which underlies the Patala Formation, is also upper Paleocene (Cheema and others, 1977; Köthe, 1988; Edwards, this volume, chap. C). Therefore, the entire Patala is probably upper Paleocene in most places. However, few fossils have been obtained from strata associated with coal beds within the Patala. In the present study, most samples from the Patala Formation are from detrital rocks closely associated with coal beds.

The lower part of the Nammal Formation at Nammal Dam has been assigned a late Paleocene age on the basis of planktic foraminifers (Gibson, this volume, chap. E, and references therein), but an early Eocene age on the basis of calcareous nannofossils (Bybell and Self-Trail, this volume, chap. B). In the Basharat corehole 34 (fig. D2, loc. 14), the Paleocene-Eocene boundary may fall within the middle part of the formation on the basis of dinoflagellates (Edwards, this volume, chap. C). However, at Nammal Dam (fig. D2, loc. 3), the lowest part of the Nammal Formation may be lower Eocene (Edwards, this volume, chap. C).

Determination of Spore-Pollen Ages

In this paper, the means of determining spore-pollen ages for samples from the Salt and Surghar Ranges has been to compare species found in these regions (1) with species found in the upper Paleocene of Sindh Province (Frederiksen, 1990) and (2) with species found by palynologists who have worked on Mesozoic and lower Tertiary sections in India (many publications describe the palynology of Indian material). However, many spore-pollen species found in the samples from the Salt and Surghar Ranges but not in Sindh Province remained unidentified because of time limitations. An important weakness in previous knowledge is that no spore-pollen assemblages from the lower Paleocene of the Indian subcontinent have been described, although assemblages of this age are presently under investigation in India (R.K. Kar, Birbal Sahni Institute of Palaeobotany, Lucknow, India, oral commun., 1989). Early Paleocene assemblages from India would have been especially useful for comparison with samples assigned to the Hangu Formation of the Salt and Surghar Ranges, which, as noted above, is thought to be lower Paleocene at least in some areas.

Figure D3 is a range chart for 27 pollen species and species groups in the upper Paleocene of the Lower Indus coal region, Sindh Province. The chart is based on pollen occurrences in 75 samples from 8 coreholes: UAL–2, UAL–13, UAJ–1, DH–18, UAK–5, UAK–7, UAT–8, and UAT–9 (Frederiksen, 1990). Stratigraphic units shown in figure D3 (see also table D1) are those of corehole UAL–13, the longest and most complete core. This core section was transformed into a single composite section for the upper Paleocene of the Lower Indus coal region by correlating it with all the other cores (using the graphic correlation charts of Frederiksen (1990)).

The species and species groups in figure D3 were stratigraphically the most significant pollen forms found in the Lower Indus samples, although many of these are new species, and therefore, their true stratigraphic ranges are not yet certain. Figure D3 does not include forms that ranged throughout the upper

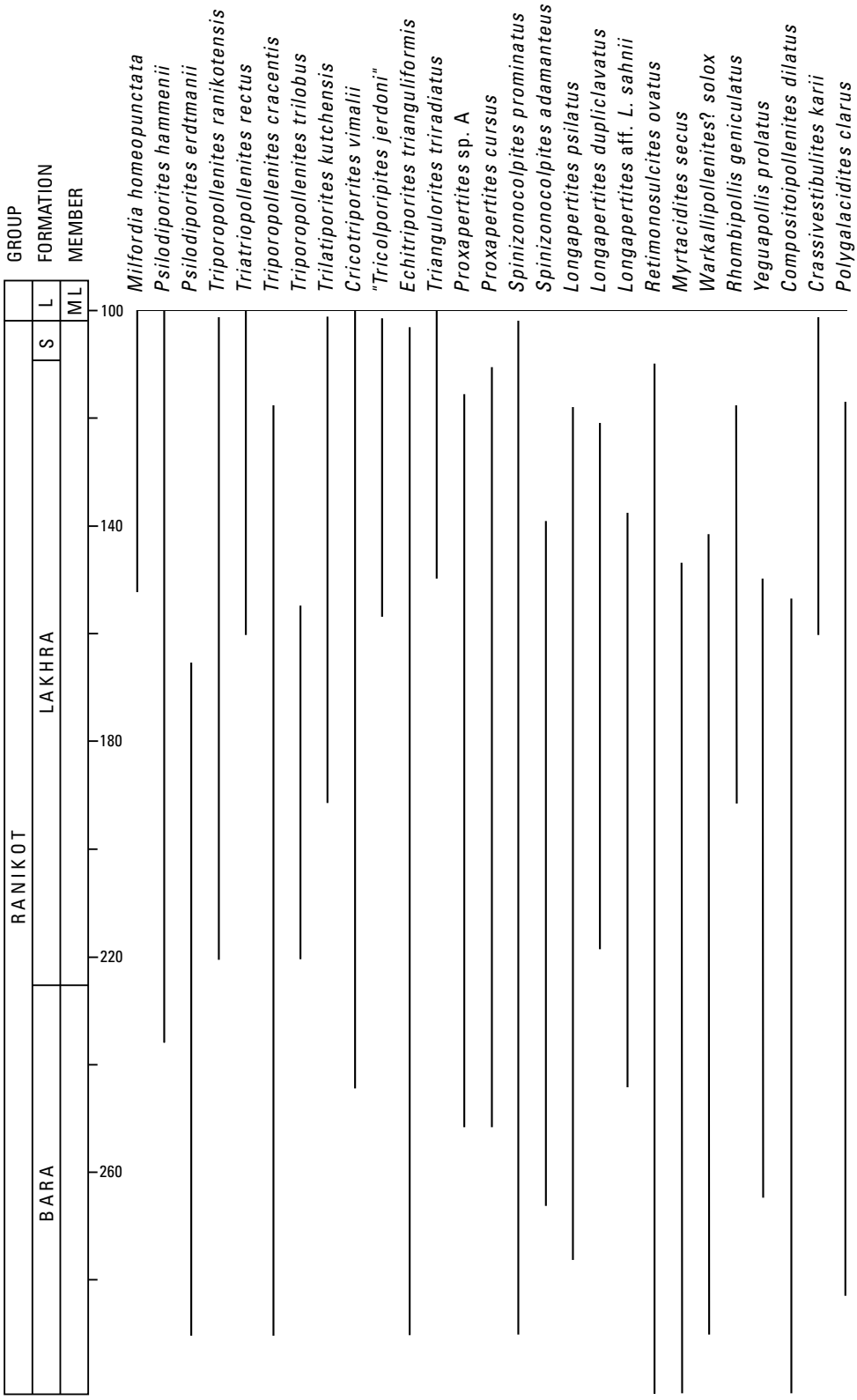

Figure D3. Range chart for 27 stratigraphically significant pollen species and species groups in a composite section for the upper Paleocene of the Lower Indus coal region, Sindh Province (data from Frederiksen, 1990). Stratigraphic units shown are those of corehole UAL–13, and each composite thickness unit represents 1 m of thickness in UAL–13. Stratigraphic nomenclature from Outerbridge and others (1991). L, Laki Formation; ML, Meting Limestone Member; S, Sohnari Formation.

Paleocene section in the Lower Indus region, nor does it include rare forms whose true range tops and bases are poorly known.

Besides the species known from the Lower Indus region, five additional early Tertiary taxa were tabulated for the samples from the Salt and Surghar Ranges. These species, and their ranges as known from India, are as follows.

Dandotiaspora dilata—apparently confined to the Paleocene (Ambwani and Kar, 1988)

Dandotiaspora telonata (pl. D3, fig. 2)—mainly Paleocene, but ranges up into the Eocene (Ambwani and Kar, 1988)

Lakiapollis ovatus (see *L.* aff. *L. ovatus* in pl. D4, fig. 1)—Paleocene to middle and upper(?) Eocene (Venkatachala and others, 1988)

Retitribrevicolporites matanomadhensis (pl. D4, fig. 4)—Paleocene to middle Eocene (Kar, 1985)

Acrostichum spp. (pl. D3, fig. 1)—This genus is interesting because (1) it is the only modern fern genus that can live consistently in brackish-water environments (it is pantropical), and (2) large abundances of *Acrostichum* spores are said to be characteristic of early Paleocene spore-pollen assemblages of India (R.K. Kar, oral commun., 1989). Because of some evidence that the Hangu Formation is at least partly early Paleocene in age, it was of interest to see whether *Acrostichum* spores were abundant in Hangu samples. However, spores identified as belonging to this genus are very rare to absent in all Paleocene and Eocene samples examined for the present report. On the other hand, there is some question whether the characteristic verrucate to coarsely granulate ornamentation found in modern *Acrostichum* spores (Nayar and others, 1964; Kremp, 1967; Thanikaimoni, 1987) is preserved very well in the fossil state. For example, Anderson and Muller (1975, p. 295) reported that *Acrostichum* spores from the Miocene and Holocene of Borneo had, "in the fossil state, a smooth exine." Thanikaimoni (1987, pl. 43, figs. 785–788) illustrated two fossil *Acrostichum* spores from Sri Lanka, one of which has a rough exine (ornamentation or a result of corrosion?) and the second of which has a smooth exine except for fine pitting, which is probably due to corrosion. In summary, it appears that most fossil *Acrostichum* spores are not easy to identify with certainty unless they are associated with obvious mangrove pollen; therefore, the rarity of obvious *Acrostichum* spores in the Paleocene of Pakistan apparently does not necessarily mean that these spores are actually rare in the samples.

Palynological Methods

Palynological samples were prepared by means of standard acid maceration. All samples underwent heavy liquid separation using $ZnCl_2$ having a specific gravity of 1.45. This unusually low specific gravity was necessary in order to remove the abundant dark woody particles from the residues and to increase the richness of the residues in the spores and pollen. The float fraction was screened on a 10-micrometer (μm) nylon sieve and mounted in glycerine jelly. When spores and pollen were present in a sample, they were usually fairly to very well preserved. Slide designations in captions for plates D1–D4 show the sample number with the slide number in parentheses. The coordinates listed in the plate descriptions locate the specimens on Leitz microscope 871956 at the U.S. Geological Survey (USGS), Reston, Va. On this microscope, the coordinates for the center point of a standard 25.4 × 76.2 mm slide are 38.8 × 102.5 (horizontal × vertical axes); the horizontal coordinates increase toward the right edge of the stage, and the vertical coordinates increase toward the front of the stage. All slides are stored at the USGS in Reston, Va.

Sample Analyses

Makarwal Coal Field

The Makarwal coal field is in the Mianwali District, Surghar Range (fig. D2, loc. 1). Palynology samples examined from this area are from Lumshiwal Nala, lat 32°51.49′ N., long 71°08.83′ E., and include samples from the Lumshiwal, Hangu, and Patala Formations (table D1). In the Makarwal coal field, Danilchik and Shah (1987, p. 17) measured 285 feet (ft) of Lumshiwal Formation in its type section, where it underlies the Hangu Formation. This type section for the Lumshiwal Formation is in Miranwal Nala, 1.7 kilometers (km) north of Lumshiwal Nala.

Palynology sample R4381A.—Field no. NF89P–1, carbonaceous shale at base of stream channel, thought to be probably Mesozoic in age or possibly from the Paleocene Hangu Formation. The stratum from which this sample was taken is probably from the Lumshiwal Formation, and apparently it lies below the measured section for the uppermost part of the Lumshiwal Formation and the Hangu Formation in Lumshiwal Nala that was described by Danilchik and Shah (1987, p. 19). The sample probably is from the same horizon as Warwick sample K–SH–1, examined by Khan (1990). Sample R4381A contains a rich spore-pollen assemblage, including *Callialasporites dampieri* (pl. D2, fig. 1), *C. segmentatus*, *C. trilobatus*, *Corollina*, *Exesipollenites*, *Araucariacites*, *Contignisporites fornicatus*, a large variety of *Gleicheniidites* types, and rare dinoflagellate cysts and *Veryhachium* acritarchs. Age is Late Jurassic or Early Cretaceous, in agreement with Khan's (1990) age determination for sample K–SH–1. As noted above, the Lumshiwal Formation in the Surghar Range was thought, on the evidence of very sparse marine fossils, to be Aptian(?) to Albian. In the Makarwal coal field, the Lumshiwal Formation is underlain by the Upper Jurassic to Lower Cretaceous (Neocomian) Chichali Formation; however, no Chichali was mapped in the area of Lumshiwal Nala (Danilchik and Shah, 1987). Therefore, in the area of Lumshiwal Nala, the Lumshiwal Formation appears to include strata of Chichali (Late Jurassic to Early Cretaceous) age.

Palynology sample R4381B.—Field no. NF89P–2, underclay below Hangu(?) coal. The sample contained only rare palynomorphs, and no age determination could be made.

Palynology sample R4381C.—Field no. NF89P–3, siltstone above the coal bed that is underlain by the clay of sample R4381B. Sample R4381C contained *Klukisporites*, *Densoisporites* (pl. D2, fig. 3), *Contignisporites glebulentus* (pl. D2, figs. 5, 6), *Coptospora kutchensis* (pl. D2, fig. 4), *Matonisporites*, and *Callialasporites segmentatus* (pl. D2, fig. 2). No dinoflagellate cysts were seen. Age is probably middle Cretaceous, approximately Aptian to Albian. There is confusion as to whether this sample comes from the same horizon as Warwick sample SH–MK–HT–1, examined by Khan (1990). Khan (1990) reported a possible Paleogene age for sample SH–MK–HT–1, which would be in conflict with the middle Cretaceous age determined for sample R4381C. However, it is possible that the coal bed near Khan's sample is the Makarwal main coal bed of Danilchik and Shah (1987, p. 19), which was considered to be in the Hangu Formation. Sample R4381C may come from the Lumshiwal Formation, possibly from the upper part of the formation, near a coal bed that is about 25 ft below the Makarwal main coal bed (Danilchik and Shah, 1987, p. 17). The doubt about sample positions and ages needs to be resolved by future collecting in the section.

Palynology sample R4381D.—Field no. NF89P–4, Hangu Formation higher in stream channel than sample R4381C. The sample contained only sparse pollen grains, few spores, and rare dinoflagellate cysts. Some variety of spore-pollen forms was present, but we are not familiar with most of them. Figure D4 lists the forms that also occur in the upper Paleocene of Sindh Province. These forms all have long ranges or are so rare that the ranges are poorly known. Age is Paleocene.

Palynology sample R4381E.—Field no. NF89P–5, carbonaceous shale associated with coal in the lower part of the Hangu Formation. The sample contained many species of angiosperm pollen, but we are not familiar with most of them. Spores are not abundant; rare dinoflagellate cysts are present. Figure D4 lists the pollen forms that also occur in the upper Paleocene of Sindh Province. These forms all have long ranges or are so rare that the ranges are poorly known, but they probably all extend well down into the Bara Formation in Sindh Province. No Late Cretaceous species (listed, for example, by Venkatachala and Sharma (1974) and Baksi and Deb (1980)) have been seen in this sample or the next lower one (R4381D). Age is Paleocene.

Palynology sample R4381F.—Field no. NF89P–6, transition zone between the Lockhart Limestone and the Patala Formation. Nearly barren of spores and pollen; rare dinoflagellate cysts are present.

Palynology sample R4381G.—Field no. NF89P–6A, Patala Formation at 403 ft in the measured section of Wardlaw and others (this volume, chap. F). Like the Paleocene Hangu samples, this sample contained many species that are unfamiliar to us. Figure D4 lists the pollen forms that also occur in the upper Paleocene of Sindh Province. These forms generally have long ranges or are so rare that the ranges are poorly known, but two species, *Cricotriporites vimalii* and *Proxapertites* sp. A, have known range bases in the upper part of the Bara Formation in Sindh Province. Furthermore, the two samples from the lower part of the Hangu Formation, R4381D and E, are more similar to each other than they are to the Patala sample R4381G. In short, the age of R4381G is presumably late Paleocene.

Palynology sample R4381H.—Field no. NF89P–7, lower part of Patala Formation at 275 ft in the measured section of Wardlaw and others (this volume, chap. F). This sample was nearly barren of palynomorphs.

Sample	*Triatriopollenites dubius*	*Cricotriporites vimalii*	*Echitriporites trianguliformis*	*Triangulorites triradiatus*	*Proxapertites* sp. A	*Proxapertites assamicus*	*Proxapertites operculatus*	*Spinizonocolpites prominatus*	*Spinizonocolpites adamanteus*	*Longapertites retipilatus*	*Tricolpites reticulatus*	*Cupanieidites granulatus*	*Polycolporopollenites calvus*	*Retistephanocolpites* spp.	*Dandotiaspora dilata*
R4381G	?	X	.	.	X	X	X	.	.	X	P	X	.	X	.
R4381E	.	.	X	X	.	X	X	X	X	X	.	.	.	.	.
R4381D	.	.	.	.	.	X	X	X	.	X	.	.	X	.	X

Figure D4. Analyses of spore-pollen assemblages from the Hangu (samples R4381D, E) and Patala (sample R4381G) Formations of Lumshiwal Nala in the Makarwal coal field. X, present; P, probably present; ?, possibly present.

Nammal Pass Section

Three samples thought to be from the Hangu Formation were collected from a coal mine dump near the road over Nammal Pass in the western Salt Range (fig. D2, loc. 2). This locality is near the base of the Nammal Pass measured section of Wardlaw and others (this volume, chap. F), at lat 32°40.75′ N., long 71°47.19′ E. Two samples from this mine dump contained sparse dinoflagellates possibly of late Paleocene age (Edwards, this volume, chap. C).

Two of the three samples collected were analyzed for spores and pollen (fig. D5): R4383A, field no. NF89P–10, gray mudstone; and R4383B, field no. NF89P–11, coal. The samples had relatively few spores, but they did contain a considerable variety of angiosperm pollen; however, most of the pollen grains represented new species, different from the pollen species known from the upper Paleocene (Ranikot Group) of Sindh Province and from the Patala Formation of the Salt Range. Age is Paleocene but older than typical Patala samples. Sample R4383A (roof mudstone) contained the pollen genus *Spinizonocolpites*, representing the brackish-water palm genus *Nypa*, as well as fragments of dinoflagellate cysts; sample R4383B (coal) contained *Spinizonocolpites*. Thus, the Hangu

Sample	*Psilodiporites hammenii*	*Triatriopollenites dubius*	*Cricotriporites vimalii*	*"Tricolporipites jerdoni"*	*Echitriporites triangulliformis*	*Triangulorites triradiatus*	*Proxapertites* sp. A	*Proxapertites assamicus*	*Proxapertites operculatus*	*Proxapertites emendatus*	*Spinizonocolpites prominatus*	*Spinizonocolpites adamanteus*	*Longapertites psilatus*	*Longapertites retipilatus*	*Longapertites discordis*	*Longapertites* sp. F	*Tricolpites reticulatus*	*Myrtacidites secus*	*Warkallipollenites? medius*	*Callophyllumpollenites* cf. *C. rotundus*	*Compositoipollenites dilatus*	*Cupanieidites flaccidiformis*	*Retistephanocolpites* spp.	*Acrostichum* sp.	*Dandotiaspora telonata*	*Retitribrevicolporites matanomadhensis*
R4384A–C	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	X
R4385C–E	.	X	X	X	.	.	X	X	.	X	X	.	.	.	X	.	X	X	.	.	P	X	X	?	X	X
R4386E	.	X	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	X	.	?	.
R4387B, C	X	.	X	X	.	X	.	X	X	.	X	.	.	.	X	X	.	.	.	X	.	X	X	?	X	.
R4383A, B	X	.	.	.	X	.	X	.	X	X	X	X	.	X	X	.	.	.	X	.	.	.	X	.	.	.

Figure D5. Analyses of spore-pollen assemblages from the Hangu Formation of Nammal Pass (samples R4383A, B) and from the Patala Formation of the Nammal Dam (samples R4384A–C), Arara (samples R4385C–E), Kuraddi (sample R4386E), and Nila Wahan (samples R4387B, C) sections. X, present; P, probably present; ?, possibly present.

coal and its roof mudstone at this locality were deposited in brackish water.

Nammal Dam Section

The Nammal Dam section is located at lat 32°39.81′ N., long 71°48.05′ E. in the western Salt Range (fig. D2, loc. 3). Three samples were examined from the Patala Formation at this locality: R4384A, field no. NF89P–13, lowest dark beds of the Patala; R4384B, field no. NF89P–14, 91 ft above the base of the Patala; and R4384C, field no. NF89P–15, 10 ft higher than sample NF89P–14.

Each of these samples contained only sparse spores and pollen grains, and analyses of the three samples are combined in figure D5. Age is late Paleocene(?). All three samples contained dinoflagellate cysts; thus, the beds were deposited in brackish-water to marine environments.

Kuraddi Section

The Kuraddi section is located 0.5 km south of the village of Kuraddi in the western Salt Range; the base of the section is at lat 32°31.67′ N., long 72°03.43′ E. (fig. D2, loc. 4; section 31 of Warwick and Shakoor (1988); section 8 of Wardlaw and others (this volume, chap. F)). The following palynology samples were examined: from the Patala Formation, R4386E, field no. NF89P–26; and from the Hangu Formation(?), R4386A, field no. NF89P–22; R4386B, field no. NF89P–23; and R4386C, field no. NF89P–24.

The three samples thought perhaps to be from the Hangu Formation were from blocks of mudstone on a pile of coal mine spoil. These samples all had the same palynomorph assemblage, characterized by (1) a high dominance (>90 percent) of the gymnosperm pollen genus *Corollina* (pl. D1, figs. 10, 11) and (2) a low diversity of other constituents, which were mainly fern spores. No dinoflagellate cysts were seen. The following spore-pollen species were identified: "*Dictyophyllidites pectinataeformis*" of Venkatachala (1969, pl. D1, fig. 12), *Concavisporites* cf. *C. jurienensis*, *Matonisporites crassiangulatus* (pl. D1, fig. 8), *Microreticulatisporites* cf. *M. telatus*, *Cingulatisporites* cf. *C. foveolatus* (pl. D1, fig. 7), *C. pseudoalveolatus* (pl. D1, fig. 9), *Cingulatisporites* spp. (pl. D1, figs. 3, 4), *Clavifera*? spp. (pl. D1, figs. 5, 6), *Ischyosporites* aff. *I. crateris*, *Baculatisporites comaumensis*, *Lycopodiacidites* aff. *L. subtriangulus*, *Acanthotriletes* cf. *A. levidensis*, and *Inaperturopollenites turbatus* (pl. D1, fig. 12). Age is Jurassic or Early Cretaceous, perhaps most likely Neocomian. It is apparent that these samples were from rocks mapped by Gee (1981) near Kuraddi as the Datta Formation; Gee considered the Datta to be Lower Jurassic.

Sample R4386E (Patala Formation) contained relatively few identified species (fig. D5). Age is presumably late Paleocene. The assemblage from this mudstone sample contained the brackish-water palm genus *Spinizonocolpites*.

Samples from the Central and Eastern Salt Range

Samples from the Patala Formation of the central and eastern Salt Range that yielded useful palynological data are in figure D6 and below.

Palynology sample R4264.—Field no. SH–S30–2, central Salt Range coal field, lat 32°27.75′ N., long 72°11.58′ E., the Punjab, Khushab District (fig. D2, loc. 5). Material studied is a grab sample of shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation and apparently with the middle part of the Lakhra Formation. The sample contained some dinoflagellate cysts.

Palynology sample R4262.—Field no. SH–ARR–HM–RT, central Salt Range coal field, lat 32°32.83′ N., long 72°20.92′ E., the Punjab, Khushab District, Hayak Ul Mir Coal Co. mine (fig. D2, loc. 6). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra or Sohnari Formation. No dinoflagellate cysts were seen, but the presence of *Spinizonocolpites* (brackish-water palm) pollen suggests brackish-water deposition.

Palynology sample R4242M.—Field no. SH–P–KB–6B, central Salt Range coal field, lat 32°36.67′ N., long 72°28.75′ E., the Punjab, Khushab District, Karam Buksh and Co. mine 6B (fig. D2, loc. 8). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation. The sample contained rare dinoflagellate cysts.

Palynology sample R4242K.—Field no. SH–PJ–PCP–1, central Salt Range coal field, lat 32°37.75′ N., long 72°31.00′ E., the Punjab, Khushab District, Punjmin-PCP mine 1 (fig. D2, loc. 9). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra or Sohnari Formation. The sample contained rare dinoflagellate cysts.

Palynology sample R4242J.—Field no. SH–M–SAL–1, central Salt Range coal field, lat 32°39.42′ N., long 72°33.42′ E., the Punjab, Chakwal District, S.A. Latif and Co. mine (fig. D2, loc. 10). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation. The sample contained some dinoflagellate cysts.

Palynology sample R4242L.—Field no. SH–P–KC–12, central Salt Range coal field, lat 32°35.50′ N., long 72°35.58′ E., the Punjab, Khushab District (fig. D2, loc. 12). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation. The sample contained rare dinoflagellate cysts.

Palynology sample R4242E.—Field no. SH–CGAS–HCC–3, eastern Salt Range coal field, lat 32°48.83′ N., long 73°06.42′ E., the Punjab, Jhelum District, Hasnain Coal Co. mine (fig. D2, loc. 15). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation or uppermost part of the Bara Formation. The sample contained sparse dinoflagellate cysts.

Sample	*Psilodiporites hammenii*	*Triporopollenites trilobus*	*Triatriopollenites dubius*	*Cricotriporites vimalii*	*"Tricolporipites jerdoni"*	*Echitriporites trianguliformis*	*Proxapertites* sp. A	*Proxapertites assamicus*	*Proxapertites operculatus*	*Proxapertites emendatus*	*Spinizonocolpites prominatus*	*Longapertites psilatus*	*Longapertites punctatus*	*Longapertites retipilatus*	*Longapertites discordis*	*Longapertites* aff. *L. sahnii*	*Longapertites* sp. F	*Retimonosulcites ovatus*	*Matanomadhiasulcites maximus*	*Brevitricolpites vadosus*	*Myrtacidites secus*	*Porocolpopollenites* aff. *P. ollivierae*	*Callophyllumpollenites* aff. *C. rotundus*	*Compositoipollenites dilatus*	*Cupanieidites flaccidiformis*	*Cupanieidites granulatus*	*Polygalacidites clarus*	*Retistephanocolpites* spp.	*Acrostichum* sp.	*Dandotiaspora dilata*	*Dandotiaspora telonata*	*Lakiapollis ovatus*	*Retitribrevicolporites matanomadhensis*
R4242D	.	.	X	X	.	X	.	X	.	.	X	X	X	X	.	X	X	.	X	X	.	.	.	.	.	X	.	X	.	.	X	.	.
R4242E	X	.	.	X	.	.	.	X	P	?	X	.	.	X	.	X	X	.	.	.	X	.	.	X	?	X	.	X	X	.	X	X	X
R4242J	X	X	.	X	P	.	.	X	X	X	.	.	X	X	.	.	X	.	X	.	.	.	.	.	X	.	.	.	.	X	X	.	.
R4242K	P	.	X	X	.	.	.	X	X	X	X	.	.	X	X	.	X	.	.	.	.	.	X	.	X	X	.	X	X	X	X	.	.
R4242L	.	.	X	X	X	.	X	X	X	X	X	.	.	X	X	.	X	X	X	.	.	.	.	.	X	.	.	X	.	X	X	.	X
R4242M	?	.	.	X	X	.	.	X	X	X	X	.	X	X	X	.	X	.	.	.	X	.	X	.	X	.	.	X	.	X	X	?	X
R4262	P	.	.	X	X	.	.	X	X	X	X	.	.	X	.	.	X	.	X	.	.	X	.	.	.	.	.	X	.	.	X	X	.
R4264	X	.	X	X	X	.	.	.	X	X	X	.	.	X	.	.	X	.	.	.	X	X	.	.	X	.	X	X	.	.	X	.	.

Figure D6. Analyses of spore-pollen assemblages from the Patala Formation of various sections in the central and eastern Salt Range. X, present; P, probably present; ?, possibly present.

Palynology sample R4242D.—Field no. SH–ARA–MC5, eastern Salt Range coal field, lat 32°44.83′ N., long 73°08.25′ E., the Punjab, Jhelum District, Munawer Corp. mine 5 (fig. D2, loc. 16). Material studied is a grab sample of coal roof shale of the Patala Formation. Age is late Paleocene, correlative with the Lakhra Formation. The sample contained sparse dinoflagellate cysts.

Arara Section

The Arara section is located 3.2 km southeast of the village of Arara, its base at lat 32°32.16′ N., long 72°23.54′ E. (fig. D2, loc. 7; section 29 of Warwick and Shakoor (1988); section 10 of Wardlaw and others (this volume, chap. F)). Five siltstone, shale, and mudstone samples were collected from a pile of coal mine spoil in the Patala Formation at this locality. Combined analyses of three of these palynology samples are given in figure D5: R4385C, field no. NF89P–18; R4385D, field no. NF89P–19; and R4385E, field no. NF89P–20.

This set of samples was relatively rich in angiosperm pollen species known from the upper Paleocene of Sindh Province. The samples contained pollen of the brackish-water palm genus *Spinizonocolpites*.

Nila Wahan Section

The Nila Wahan section is located at a north point dividing major drainages to Nila Wahan Gorge, 2 km southeast of the village of Bhal; the base of the Lockhart Limestone is at lat 32°38.67′ N., long 72°35.75′ E. (fig. D2, loc. 11; section 20 of Warwick and Shakoor (1988); section 13 of Wardlaw and others (this volume, chap. F)). Three mudstone samples were collected from a pile of coal mine spoil in the Patala Formation at this locality; combined analyses of two of these palynology samples are given in figure D5: R4387B, field no. NF89P–28; and R4387C, field no. NF89P–29.

These samples contained a fair number of angiosperm pollen species known from the upper Paleocene of Sindh Province. No dinoflagellate cysts were found, but pollen of the brackish-water palm genus *Spinizonocolpites* was present.

Drill Hole 9, Khairpur Area

Drill hole 9 in the Khairpur area is at lat 32°44.67′ N., long 72°47.00′ E. (fig. D2, loc. 13). Only samples processed for palynomorphs are listed below; samples marked with an asterisk were barren or contained only rare palynomorphs. Depths are in feet below ground surface. Analyses of three usable spore-pollen assemblages from the Patala Formation are given in figure D7.

Nammal Formation

Four palynology samples were processed from the Nammal Formation: R4372C*, 210.5–210.7 ft; R4372D*, 301.0–301.4 ft; R4372E*, 335.3–335.6 ft; and R4372F*, 405.7–406.0 ft.

Patala Formation

Palynology sample R4372J, 421.1–421.5 ft, is of late Paleocene age, correlative with the Lakhra Formation or the uppermost part of the Bara Formation. Palynology sample R4372N, 446.6–446.9 ft, contained only sparse spores and pollen grains but did contain dinoflagellate cysts. Palynology sample R4372O, 457.9–458.0 ft, is probably of late Paleocene age and contained rare dinoflagellate cysts. Palynology sample

Sample	*Cricotriporites vimalii*	*"Tricolporipites jerdoni"*	*Proxapertites assamicus*	*Proxapertites operculatus*	*Proxapertites emendatus*	*Spinizonocolpites prominatus*	*Longapertites psilatus*	*Longapertites punctatus*	*Longapertites retipilatus*	*Longapertites discordis*	*Longapertites* aff. *L. sahnii*	*Longapertites* sp. F	*Matanomadhiasulcites maximus*	*Porocolpopollenites* aff. *P. ollivierae*	*Cupanieidites* aff. *C. flabelliformis*	*Cupanieidites flaccidiformis*	*Retistephanocolpites* spp.	*Acrostichum* sp.	*Dandotiaspora dilata*	*Dandotiaspora telonata*	*Retitribrevicolporites matanomadhensis*
R4372J	X	.	X	.	.	.	X	X	.	.	P	.	.	X	.	.	X	P	.	.	.
R4372O	X	P	X	X	X	X	.	X	X	X	.	X	.	.	.	X	X	P	.	X	X
R4372Q	X	.	X	X	.	X	.	X	X	X	.	.	X	.	X	X	X	.	X	X	.

Figure D7. Analyses of spore-pollen assemblages from the Patala Formation of drill hole 9, Khairpur area. X, present; P, probably present.

R4372Q, 465.3–465.7 ft, is of late Paleocene age. No dinoflagellate cysts were seen, but the presence of genus *Spinizonocolpites* (brackish-water palm) pollen suggests at least brackish-water deposition. Also processed were palynology samples R4372K*, 431.7–432.2 ft; R4372R*, 476.2–476.4 ft; and R4372S*, 479.4–479.5 ft.

Lockhart Limestone

Four palynology samples were processed from the Lockhart Limestone: R4372T*, 483.3–483.4 ft; R4372V*, 488.8–489.3 ft; R4372W*, 500.0–500.3 ft; and R4372Y*, 512.7–513.3 ft.

Drill Hole 34, Basharat Area

Drill hole 34 in the Basharat area of the eastern Salt Range is at lat 32°46.87′ N., long 73°05.95′ E. (fig. D2, loc. 14). Only samples processed for palynomorphs are listed below; samples marked with an asterisk were barren or contained only rare palynomorphs. Depths are in feet below ground surface.

Palynology samples from the Nammal Formation are R4379A*, 86.0–86.2 ft; R4379B, 94.0–94.2 ft; R4379C*, 96.9–97.1 ft; R4379D, 106.0–106.2 ft; R4379K*, 141.5–141.8 ft; R4379O*, 171.1–171.4 ft; R4379P*, 181.7–181.9 ft; and R4379S*, 203.7–204.0 ft.

Palynology samples from the Patala Formation are R4379U*, 224.2–224.3 ft; R4379X, 245.6–245.9 ft; R4379Y, 257.0–257.3 ft; R4379Z, 266.9–267.1 ft; R4379AB*, 286.0–286.2 ft; and R4379AD*, 305.7–306.0 ft.

Palynology sample R4379AE, 326.8–327.0 ft, is from the Tobra(?) Formation.

Sample R4379AE, near the base of the drill hole, was a conglomerate thought by the well-site geologists to be from the Tobra Formation (Permian). This sample contained dark-brown, well-preserved Permian pollen grains and spores (pl. D1, figs. 1, 2) that could be either indigenous or reworked. There were also a few monosulcate gymnosperm grains of *Ginkgo*-cycad-cycadeoid type, which are probably Permian or Mesozoic. Light-brown palynomorphs were also present that seemed to be younger than Permian. Most of these were smooth inaperturate grains of unknown affinity (that is, it is unknown whether they represent gymnosperm pollen or marine palynomorphs), but no obvious dinoflagellate cysts were present. However, these smooth inaperturate grains might be contaminants in the coarse-grained rock. In short, the age of the sample could be Permian or younger.

Analyses of three usable spore-pollen assemblages from the Patala Formation and two from the Nammal Formation are given in figure D8. The three Patala samples from the Basharat drill hole contained the richest spore-pollen flora of any Patala samples examined for this report, no doubt partly because the site of deposition was close to the land area that was the source of the spores and pollen grains, and partly because these were unweathered core samples in which the spores and pollen were unusually well preserved. These Patala samples correlate with the Lakhra Formation of Sindh Province, but they contain quite a few pollen species that do not range as high as the top of the Lakhra (*Proxapertites* sp. A; *Longapertites psilatus*, *L. dupliclavatus*; *L.* aff. *L. sahnii*; *Myrtacidites secus*; *Rhombipollis geniculatus*; *Polygalacidites clarus*). Sparse dinoflagellate cysts were found in two of the Patala samples, and all three also contained brackish-water *Spinizonocolpites* pollen; thus, the samples appear to have been deposited in brackish water.

Sample	*Psilodiporites hammenii*	*Triporopollenites cracentis*	*Triatriopollenites dubius*	*Cricatriporites vimalii*	*Echitriporites triangulíformis*	*Proxapertites* sp. A	*Proxapertites assamicus*	*Proxapertites operculatus*	*Proxapertites cursus*	*Proxapertites emendatus*	*Spinizonocolpites prominatus*	*Clavainaperturites* cf. *C. clavatus*	*Longapertites psilatus*	*Longapertites retipilatus*	*Longapertites discordis*	*Longapertites dupliclavatus*	*Longapertites* aff. *L. sahnii*	*Longapertites* sp. F	*Matanomadhiasulcites maximus*	*Brevitricolpites vadosus*	*Tricolpites reticulatus*	*Myrtacidites secus*	*Warkallipollenites*? *medius*	*Rhombipollis geniculatus*	*Porocolpopollenites* aff. *P. ollivierae*	*Callophyllumpollenites* aff. *C. rotundus*	*Cupanieidites* aff. *C. flabelliformis*	*Cupanieidites flaccidiformis*	*Cupanieidites granulatus*	*Polygalacidites clarus*	*Retistephanocolpites* spp.	*Dandotiaspora dilata*	*Dandotiaspora telonata*	*Lakiapollis ovatus*	*Psilodiporites bengalensis*	*Retitribrevicolporites matanomadhensis*
R4379B	.	.	.	.	.	.	X	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X
R4379D	X	.	.	X	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
R4379X	.	.	X	X	.	.	X	X	.	.	X	X	X	.	X	.	.	X	.	.	.	.	X	.	.	.	.	X	.	.	X	.	.	.	.	X
R4379Y	.	P	X	X	.	.	X	X	.	X	X	X	X	X	.	X	X	X	.	X	.	X	X	.	X	X	X	X	X	X	X	X	.	X	X	X
R4379Z	.	.	X	X	P	X	X	X	X	X	X	.	X	.	.	.	.	.	X	.	.	.	X	X	.	.	.	X	X	.	X	.	X	.	.	.

Figure D8. Analyses of spore-pollen assemblages from the Patala Formation (samples R4379X, Y, Z) and Nammal Formation (samples R4379B, D) of drill hole 34, Basharat area. X, present; P, probably present.

Samples R4379B and D were the only samples from the Nammal Formation examined for this report that contained more than a few spores and pollen grains. In this drill hole, in the eastern part of the Salt Range, the Nammal includes a sequence of pyritic, sparsely fossiliferous, dark-gray shale nearly 20 ft thick, and the two pollen-bearing samples came from this shale sequence. Sparse dinoflagellates in the sequence indicated that the Paleocene-Eocene boundary may fall near sample R4379K (Edwards, this volume, chap. C), which would mean that our spore-pollen samples R4379B and D would be early Eocene in age.

Spores and pollen grains are fairly abundant in the two samples (pl. D4, figs. 11–15), but the taxonomic diversity of these fossils is low (figs. D8, D9). Some species were found that were not known from the Patala Formation or from the upper Paleocene of Sindh Province, but the main characteristic of the Nammal assemblages was the high dominance by a few species of pollen, apparently from wind-pollinated plants, mainly of the genera *Proxapertites* and *Retistephanocolpites*. At least partly because of the low pollen diversity in the Nammal samples, no species known to be restricted to the Eocene were found in these samples. Rare dinoflagellate cysts were found in one of the Nammal samples (R4379B), but pollen of the genus *Spinizonocolpites* (brackish-water palm) was not seen in either sample from this formation.

Discussion and Conclusions

This report concerns spore-pollen analyses of 38 Permian(?), Mesozoic, and lower Tertiary samples from the Surghar and Salt Ranges. These samples consist of 1 from the Tobra(?) Formation (Permian or younger), 2 from the Lumshiwal Formation (Mesozoic), 7 from rocks thought at least tentatively to belong to the Hangu Formation (Paleocene), 26 from the Patala Formation (probably Paleocene), and 2 from the Nammal Formation (Eocene(?)).

The conglomerate at the base of the Basharat drill hole 34 (eastern Salt Range), thought by the well-site geologists to represent the Tobra Formation (Permian), contained dark-brown Permian pollen grains and spores (indigenous or reworked?), but it also contained light-brown palynomorphs that may be Mesozoic or may be contaminants. Therefore, the age of this conglomerate is uncertain.

Of the two samples from the lower part of Lumshiwal Nala (Makarwal coal field, Surghar Range), probably from the Lumshiwal Formation, one was assigned a Late Jurassic to Early Cretaceous age and the other was assigned a middle Cretaceous (approximately Aptian to Albian) age.

Four Paleocene samples were analyzed from strata assigned to the Hangu Formation. Two of these samples were from Lumshiwal Nala in the Surghar Range, and two were from Nammal Pass in the western Salt Range. Two dinoflagellate assemblages from the Hangu Formation at Nammal Pass (same mine dump as samples examined here for spores

Formation	Nammal Fm.	Patala Fm.	Hangu Fm.
Psiladiporites hammenii	X	P	X
Triporopollenites cracentis	•	•	•
Triporopollenites triobus	•	X	•
Triatriopollenites dubius	•	X	•
Cricotriporites vimalii	X	X	•
"Tricoporipites jerdoni"	•	X	•
Echitriporites triangulliformis	•	X	•
Triangulorites triradiatus	•	X	X
Proxapertites sp. A	•	X	X
Proxapertites assamicus	X	X	X
Proxapertites operculatus	X	X	X
Proxapertites cursus	•	X	•
Proxapertites emendatus	X	X	X
Spinizonocolpites prominatus	•	X	X
Spinizonocolpites adamanteus	•	•	X
Clavainaperturites cf. *C. clavatus*	•	X	•
Longapertites psilatus	•	X	•
Longapertites punctatus	•	X	•
Longapertites reticulatus	X	X	X
Longapertites discordis	•	X	X
Longapertites duplicilavatus	•	X	•
Longapertites aff. *L. sahnii*	•	X	•
Longapertites sp. F	•	X	•
Reitmonosulcites ovatus	•	X	•
Matanomadiasulcites maximus	•	X	•
Brevitricolpites vadosus	•	X	•
Tricolpites reticulatus	X	X	•
Myrtacidites secus	•	X	•
Warkalliipollenites? medius	•	X	X
Rhombipollis genicularus	•	X	•
Porocolpopollenites aff. *P. ollivierae*	•	X	•
Callophyllumpollenites aff. *C. rotundus*	•	X	•
Compositiopollenites dilatus	•	X	•
Cupanieidites aff. *C. flabelliformis*	•	X	•
Cupanieidites flaccidiformis	•	X	•
Cupanieidites granulatus	•	X	•
Polygalacidites clarus	•	X	•
Polycolporopollenites calvus	X	•	•
Retistephanocolpites spp.	X	X	X
Acrostichum sp.	•	X	P
Dandotiaspora dilata	•	X	X
Dandotiaspora telonata	•	X	•
Lakiapollis ovatus	•	X	•
Psiladiporites bengalensis	•	X	•
Retitribreviciporites matanomadhensis	X	X	•

Figure D9. Composite analyses of spore-pollen assemblages from the Hangu, Patala, and Nammal Formations of the Surghar and Salt Ranges. The only species listed are those that were also tabulated from the Ranikot Group and lower part of the Laki Formation in Sindh Province (Frederiksen, 1990), in addition to several species from the Surghar and Salt Ranges. X, present; P, probably present.

and pollen) were assigned a possible late Paleocene age by Edwards (this volume, chap. C). The spore-pollen samples contained a considerable variety of angiosperm pollen, but most of the pollen grains represented new species, different from species of the upper Paleocene of Sindh Province and at least to some degree different from species in the Patala Formation of the Salt Range. The disparity between the Hangu and Patala assemblages is shown in figure D9, where the Hangu assemblages appear to have a low diversity only because so many of the Hangu species are new. Some new species in the Hangu Formation might range up into the Patala Formation in this region, but the new species have not been studied to determine their stratigraphic ranges.

Paleocene coal beds in the Hangu Formation were undoubtedly deposited in or near brackish water because dinoflagellate cysts and pollen of the brackish-water palm genus *Spinizonocolpites* were found in the associated detrital rocks. Three samples tentatively attributed to the Hangu Formation were also examined from the shallow subsurface of the Kuraddi section in the western Salt Range. These samples were found to be Jurassic or Lower Cretaceous and therefore were probably from the Datta Formation (Mesozoic).

Twenty-six samples of the Patala Formation were studied from 15 localities, ranging geographically from the Surghar Range to the eastern Salt Range. The main coal bed in the Patala Formation is mostly in the lower or middle part of the formation (Warwick and Shakoor, 1988), which is upper Paleocene from evidence of marine fossils in underlying and overlying rocks. The uppermost part of the Patala is mostly upper Paleocene but has been assigned to the lower Eocene in a few places on the basis of marine fossils.

Spore-pollen assemblages from the Patala Formation were similar (in some cases, very similar) to assemblages from the upper Paleocene Lakhra Formation of Sindh Province. However, the spore-pollen assemblages could not be used to prove conclusively that all of the Patala samples studied for this report were late Paleocene in age. Practically no information is available from Sindh Province about changes in spore-pollen assemblages across the Paleocene-Eocene boundary, and as far as we know, no papers have been published on the palynology of this boundary in India.

Nearly all the Patala samples contained pollen of the brackish-water palm genus *Spinizonocolpites* and (or) dinoflagellate cysts. Thus, the Patala samples all or nearly all formed in brackish water, and the coal beds, with which most of the samples were associated, undoubtedly formed near the sea.

Only two samples from the Nammal Formation had usable spore-pollen assemblages; these samples were from drill hole 34 in the Basharat area of the eastern Salt Range. The samples may be lower Eocene on the basis of dinoflagellate assemblages from this corehole (Edwards, this volume, chap. C). These spore-pollen assemblages were characterized by high dominance and low diversity and were not definitive as to a late Paleocene or early Eocene age.

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Appendix D1. Alphabetical List of Species Mentioned in this Report

[An asterisk denotes an informal species name used by Frederiksen (1990). Plate and figure citations refer to illustrations in the present paper]

Acanthotriletes cf. *A. levidensis* Balme 1957
Acrostichum sp.; pl. D3, fig. 1

Baculatisporites comaumensis (Cookson 1953) Potonié 1956
Brevitricolpites vadosus Frederiksen 1994

Callialasporites dampieri (Balme 1957) Dev 1961; pl. D2, fig. 1
Callialasporites segmentatus (Balme 1957) Dev 1961; pl. D2, fig. 2
Callialasporites trilobatus (Balme 1957) Dev 1961
Callophyllumpollenites aff. *C. rotundus* Sah & Kar 1974; pl. D3, fig. 12
Cingulatisporites cf. *C. foveolatus* Couper 1958; pl. D1, fig. 7
Cingulatisporites pseudoalveolatus Couper 1958; pl. D1, fig. 9
Cingulatisporites spp.; pl. D1, figs. 3, 4
Clavainaperturites cf. *C. clavatus* van der Hammen & Wymstra 1964
Clavifera? spp.; pl. D1, figs. 5, 6
Compositoipollenites dilatus Frederiksen 1994
Concavisporites cf. *C. jurienensis* Balme 1957
Contignisporites fornicatus Dettmann 1963
Contignisporites glebulentus Dettmann 1963; pl. D2, figs. 5, 6
Coptospora kutchensis Venkatachala 1969; pl. D2, fig. 4
Cordaitina sp.; pl. D1, fig. 2
Corollina spp.; pl. D1, figs. 10, 11
Couperipollis sp.; pl. D2, fig. 8
Crassivestibulites karii Frederiksen 1994
Cricotriporites vimalii (Sah & Dutta 1966) Frederiksen 1994
Cupanieidites aff. *C. flabelliformis* Venkatachala & Rawat 1972
Cupanieidites flaccidiformis Venkatachala & Rawat 1972; pl. D4, fig. 6
Cupanieidites granulatus Jain, Kar & Sah 1973
Cupanieidites sp.; pl. D4, fig. 7
Cupuliferoipollenites sp.; pl. D4, fig. 16

Dandotiaspora dilata Sah et al. 1971
Dandotiaspora telonata Sah et al. 1971; pl. D3, fig. 2
Densoisporites sp.; pl. D2, fig. 3
Dictyophyllidites pectinataeformis (Bolkhovitina 1953) Dettmann 1963
"Dictyophyllidites pectinataeformis" of Venkatachala (1969, pl. D1, fig. 12)

Echitriporites trianguliformis van Hoeken-Klinkenberg 1964; pl. D2, fig. 7

Genus? sp., rugulate, oblate, tricolpate; pl. D4, fig. 3
Genus? sp., psilate-punctate spheroidal tricolporate; pl. D4, fig. 8

Inaperturopollenites turbatus Balme 1957; pl. D1, fig. 12
Ischyosporites aff. *I. crateris* Balme 1957

Klukisporites sp.

Lakiapollis ovatus Venkatachala & Kar 1969
Lakiapollis aff. *L. ovatus*; pl. D4, fig. 1
Lakiapollis cf. *L. ovatus*; pl. D4, fig. 2
Longapertites discordis Frederiksen 1994; pl. D3, fig. 9
Longapertites dupliclavatus Frederiksen 1994
Longapertites psilatus Frederiksen 1994
Longapertites punctatus Frederiksen 1994
Longapertites retipilatus Kar 1985; pl. D4, fig. 12
Longapertites aff. *L. sahnii* Rao & Ramanujam 1978
Longapertites sp. F*
Lunatisporites sp.; pl. D1, fig. 1
Lycopodiacidites aff. *L. subtriangulus* Venkatachala et al. 1969

Matanomadhiasulcites maximus (Saxena 1979) Kar 1985; pl. D3, fig. 8
Matonisporites crassiangulatus (Balme 1957) Dettmann 1963; pl. D1, fig. 8
Microreticulatisporites cf. *M. telatus* Balme 1957
Milfordia homeopunctata (McIntyre 1965) Partridge in Stover & Partridge 1973
Myrtacidites secus Frederiksen 1994; pl. D3, fig. 11

Cf. *Nyssoidites (Nyssa) ingentipollinius* (Traverse 1955) Potonié 1960 of Jain and others (1973); pl. D4, fig. 5

Polycolporopollenites calvus Frederiksen 1994
Polygalacidites clarus Sah & Dutta 1966
Porocolpopollenites aff. *P. ollivierae* (Gruas-Cavagnetto 1976) Frederiksen 1983
Proteacidites? sp.; pl. D3, fig. 5
Proxapertites assamicus (Sah & Dutta 1966) Singh 1975; pl. D3, fig. 7
Proxapertites cursus van Hoeken-Klinkenberg 1966
Proxapertites emendatus (Sah & Dutta 1976) Kar & Kumar 1986; pl. D3, fig. 6
Proxapertites operculatus (van der Hammen 1954) van der Hammen 1956; pl. D4, fig. 11
Proxapertites sp. A*

Psilodiporites bengalensis (Varma & Rawat 1963) Venkatachala & Rawat 1972; pl. D3, fig. 4
Psilodiporites erdtmanii (Varma & Rawat 1963) Venkatachala & Rawat 1972
Psilodiporites hammenii Varma & Rawat 1963

Retimonosulcites ovatus (Sah & Kar 1970) Kar 1985
Retistephanocolpites spp.; pl. D3, fig. 10
Retitrescolpites sp. B*
Retitribrevicolporites matanomadhensis (Venkatachala & Kar 1969) Kar 1985; pl. D4, fig. 4
Rhombipollis geniculatus Frederiksen 1994

Spinizonocolpites adamanteus Frederiksen 1994
Spinizonocolpites prominatus (McIntyre 1965) Stover & Evans 1973

Tetracolporopollenites sp.; pl. D4, fig. 10
Triangulorites sp. A*
Triangulorites triradiatus (Saxena 1979) Kar 1985
Triatriopollenites dubius (Venkatachala & Rawat 1972) Frederiksen 1994; pl. D3, fig. 3
Triatriopollenites rectus Frederiksen 1994
Tricolpites reticulatus Couper 1953; pl. D4, fig. 14
Tricolpites sp.; pl. D4, fig. 15
"Tricolporipites jerdoni" Biswas 1962
Tricolporopollis decoris Dutta & Sah 1970; pl. D4, fig. 9
Trilatiporites kutchensis Venkatachala & Kar 1969; pl. D4, fig. 13
Triporopollenites cracentis Frederiksen 1994
Triporopollenites ranikotensis Frederiksen 1994
Triporopollenites trilobus Frederiksen 1994

Warkallipollenites? *medius* Frederiksen 1994
Warkallipollenites? *solox* Frederiksen 1994

Yeguapollis prolatus Frederiksen 1994

Plates D1–D4

Plate D1

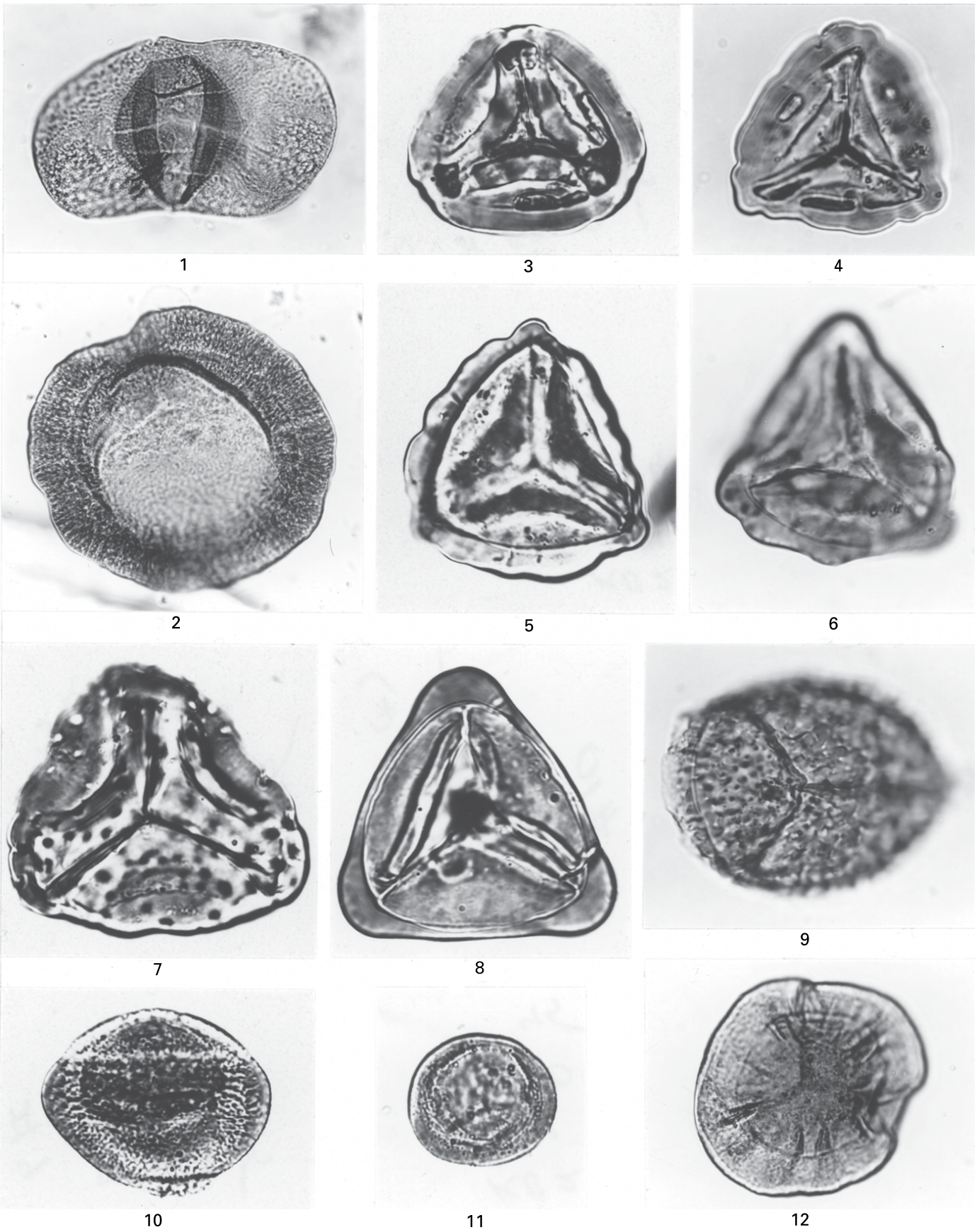
[Magnification × 1,000 unless otherwise noted; see scale in pl. D2]

Figures 1, 2. Permian gymnosperm pollen from the Basharat drill hole 34, eastern Salt Range.

1. *Lunatisporites* sp.; slide R4379AE(1), coordinates 50.7 × 104.6. Maximum dimension 93 μm.
2. *Cordaitina* sp.; slide R4379AE(1), coordinates 60.2 × 105.4. Maximum dimension 95 μm.

3–12. Jurassic or Early Cretaceous spores and gymnosperm pollen from the Kuraddi section, western Salt Range.

3. *Cingulatisporites* sp.; slide R4386C(4), coordinates 48.5 × 104.3.
4. *Cingulatisporites* sp.; slide R4386A(4), coordinates 40.1 × 106.6.
5. *Clavifera*? sp.; slide R4386C(4), coordinates 60.3 × 99.7.
6. *Clavifera*? sp.; slide R4386C(4), coordinates 47.9 × 98.3.
7. *Cingulatisporites* cf. *C. foveolatus* Couper 1958; slide R4386C(4), coordinates 49.4 × 109.4.
8. *Matonisporites crassiangulatus* (Balme 1957) Dettmann 1963; slide R4386B(3), coordinates 55.6 × 106.2.
9. *Cingulatisporites pseudoalveolatus* Couper 1958; slide R4386C(4), coordinates 43.0 × 97.7.
10. *Corollina* sp., equatorial view; slide R4386A(4), coordinates 44.4 × 105.4.
11. *Corollina* sp., polar view; slide R4386A(2), coordinates 49.1 × 104.7.
12. *Inaperturopollenites turbatus* Balme 1957; slide R4386B(3), coordinates 67.4 × 99.4. Maximum dimension 75 μm.



Permian and Jurassic or Early Cretaceous Spores and Gymnosperm Pollen from the Salt Range

Plate D2

[Magnification × 1,000; see scale]

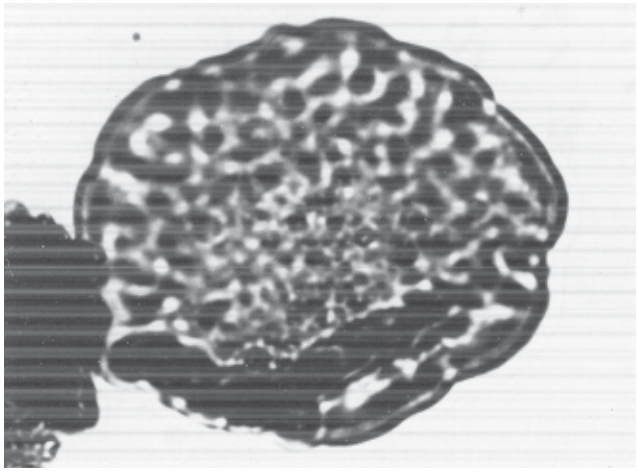
Figures 1–6. Late Jurassic or Early Cretaceous (fig. 1) and probably middle Cretaceous, approximately Aptian to Albian (figs. 2–6) spores and gymnosperm pollen from Lumshiwal Nala, Makarwal coal field, Surghar Range.

1. *Callialasporites dampieri* (Balme 1957) Dev 1961; slide R4381A(1), coordinates 51.0 × 96.1.
2. *Callialasporites segmentatus* (Balme 1957) Dev 1961; slide R4381C(1), coordinates 39.9 × 111.9.
3. *Densoisporites* sp.; slide R4381C(1), coordinates 40.8 × 101.9.
4. *Coptospora kutchensis* Venkatachala 1969; slide R4381C(1), coordinates 41.3 × 109.6.

5, 6. *Contignisporites glebulentus* Dettmann 1963; slide R4381C(1), coordinates 41.6 × 107.5.

7, 8. Paleocene angiosperm pollen from the Hangu Formation, Nammal Pass section, western Salt Range.

7. *Echitriporites trianguliformis* van Hoeken-Klinkenberg 1964; slide R4383B(1), coordinates 49.7 × 99.7.
8. *Couperipollis* sp.; slide R4383A(2), coordinates 54.4 × 106.4.



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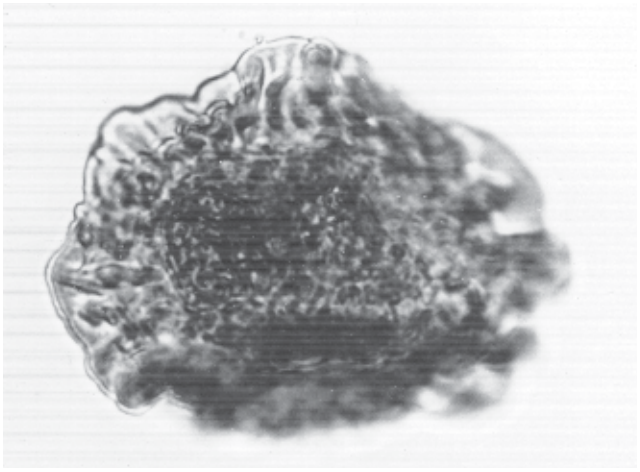

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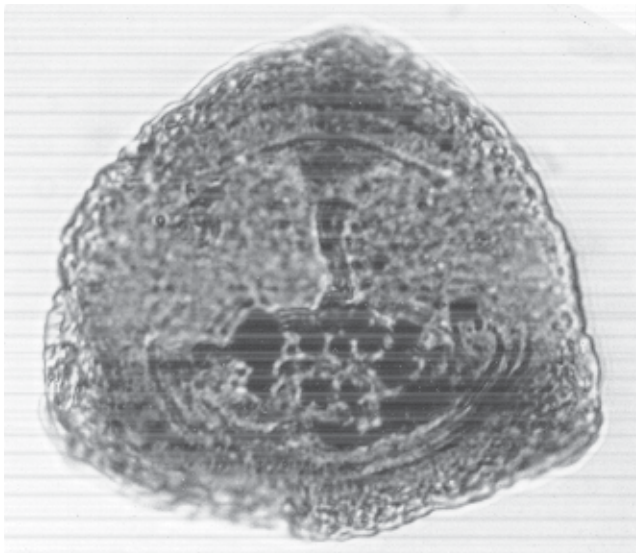

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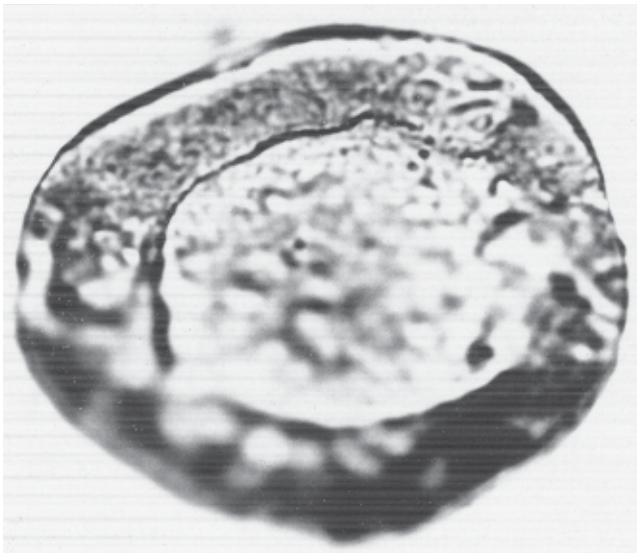

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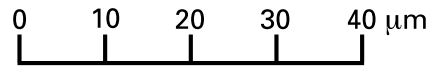

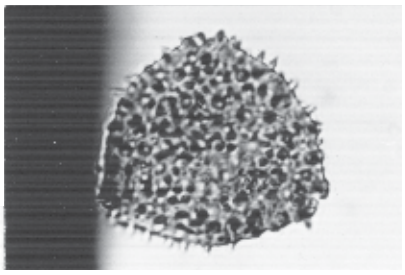

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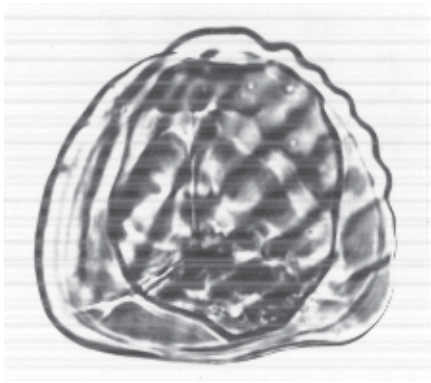

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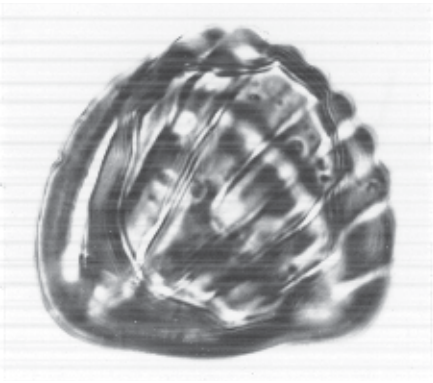

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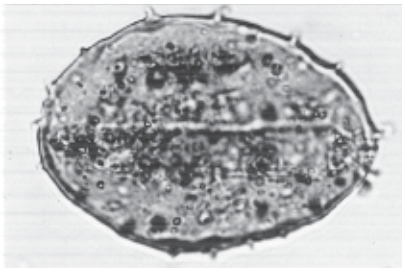


8

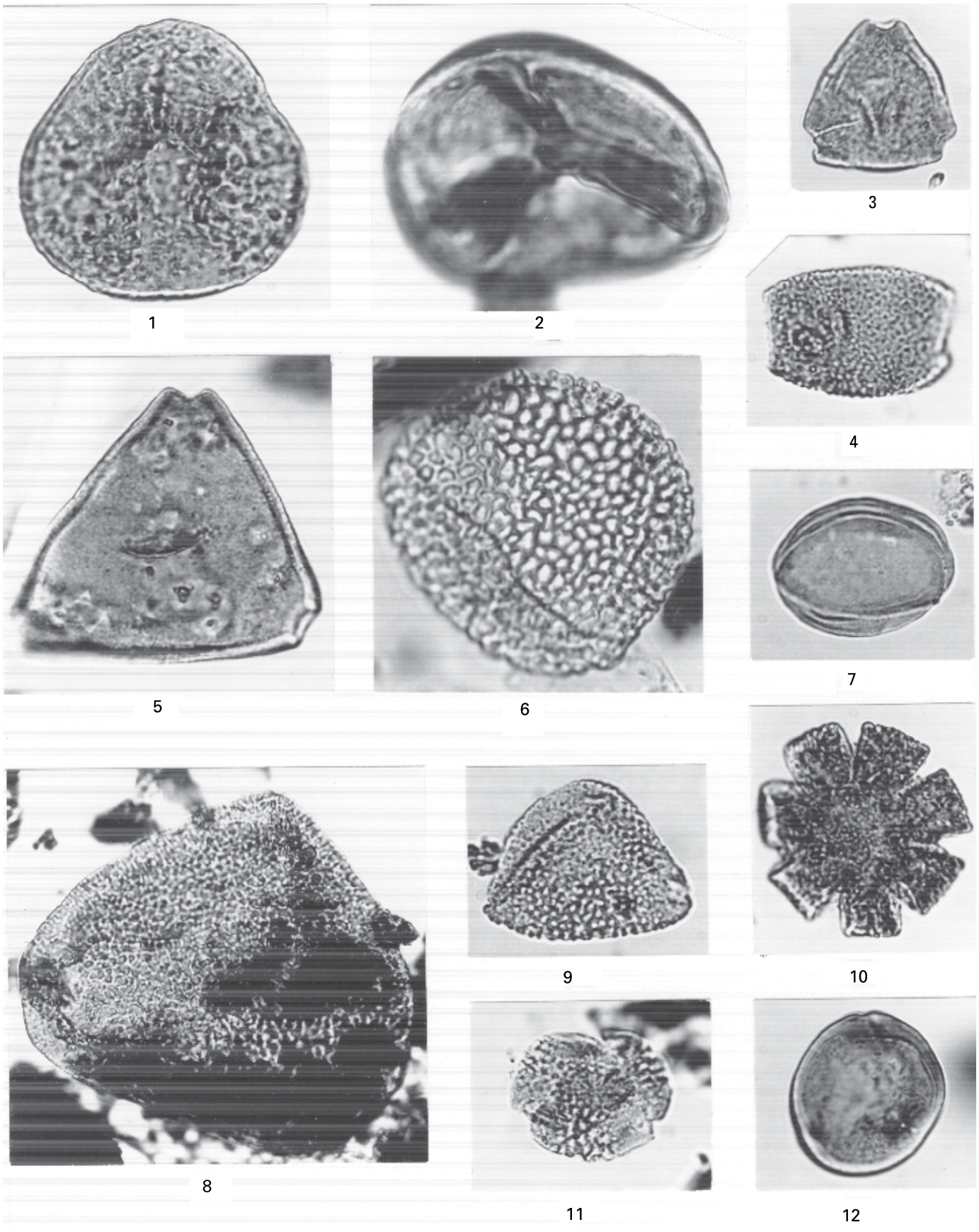
Late Jurassic or Early Cretaceous, Probably Middle Cretaceous, and Paleocene Spores and Pollen from the Surghar and Salt Ranges

Plate D3

[Magnification × 1,000 unless otherwise noted; see scale in pl. D2]

Figures 1–12. Spores and angiosperm pollen from the Patala Formation of the Salt Range.

1. *Acrostichum* sp.; slide R4242K(4), coordinates 51.3 × 97.9.
2. *Dandotiaspora telonata* Sah et al. 1971; slide R4372O(2), coordinates 52.8 × 104.6.
3. *Triatriopollenites dubius* (Venkatachala & Rawat 1972) Frederiksen 1994; slide R4242L(3), coordinates 49.5 × 106.7.
4. *Psilodiporites bengalensis* (Varma & Rawat 1963) Venkatachala & Rawat 1972; slide R4379Y(1), coordinates 39.8 × 112.0.
5. *Proteacidites*? sp.; slide R4262(4), coordinates 38.4 × 107.9.
6. *Proxapertites emendatus* (Sah & Dutta 1966) Kar & Kumar 1986; slide R4242K(4), coordinates 51.1 × 106.4.
7. *Proxapertites assamicus* (Sah & Dutta 1966) Singh 1975; slide R4385E(2), coordinates 35.1 × 100.9.
8. *Matanomadhiasulcites maximus* (Saxena 1979) Kar 1985; slide R4379Z(2), coordinates 52.1 × 95.2. Maximum dimension 168 μm.
9. *Longapertites discordis* Frederiksen 1994; slide R4242M(3), coordinates 51.9 × 104.9.
10. *Retistephanocolpites* sp.; slide R4379Y(1), coordinates 34.6 × 96.8.
11. *Myrtacidites secus* Frederiksen 1994; slide R4379Z(2), coordinates 54.0 × 110.5.
12. *Callophyllumpollenites* aff. *C. rotundus* Sah & Kar 1974; slide R4379Y(1), coordinates 52.0 × 98.0.



Spores and Angiosperm Pollen from the Patala Formation of the Salt Range

Plate D4

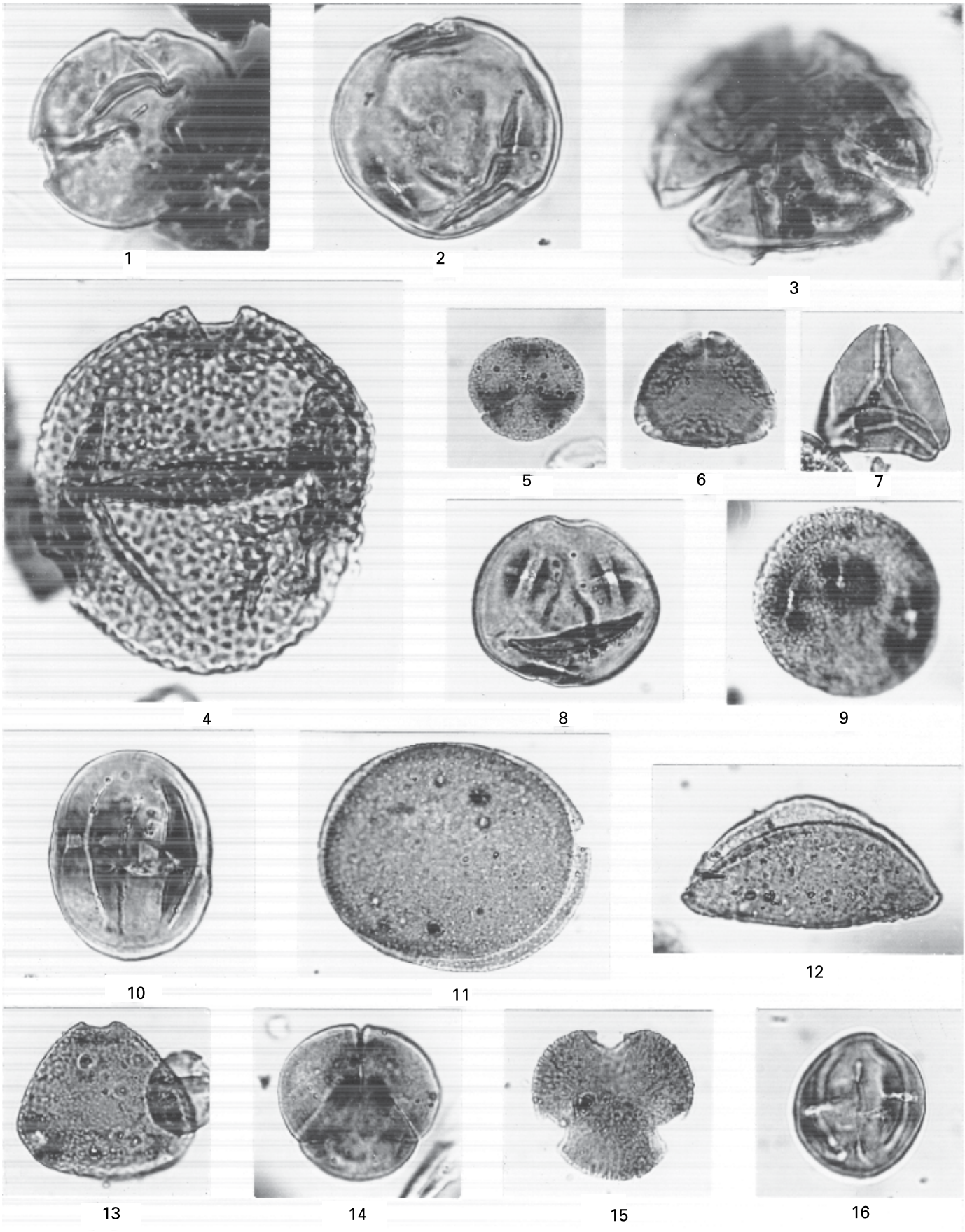
[Magnification × 1,000; see scale in pl. D2]

Figures 1–10. Angiosperm pollen from the Patala Formation of the Salt Range.

1. *Lakiapollis* aff. *L. ovatus* Venkatachala & Kar 1969; slide R4242E(3), coordinates 61.5 × 107.1.
2. *Lakiapollis* cf. *L. ovatus* Venkatachala & Kar 1969; slide R4372O(2), coordinates 55.3 × 106.6.
3. Genus? sp., rugulate, oblate, tricolpate; slide R4379Z(2), coordinates 50.2 × 92.6.
4. *Retitribrevicolporites matanomadhensis* (Venkatachala & Kar 1969) Kar 1985; slide R4379Y(1), coordinates 44.7 × 98.6.
5. Cf. *Nyssoidites* (*Nyssa*) *ingentipollinius* (Traverse 1955) Potonié 1960 of Jain and others (1973); slide R4379X(2), coordinates 55.6 × 97.0.
6. *Cupanieidites flaccidiformis* Venkatachala & Rawat 1972; slide R4379X(2), coordinates 61.6 × 106.6.
7. *Cupanieidites* sp.; slide R4262(4), coordinates 41.5 × 95.2.
8. Genus? sp., psilate-punctate spheroidal tricolporate; slide R4379X(2), coordinates 48.0 × 107.4.
9. *Tricolporopollis decoris* Dutta & Sah 1970; slide R4379X(2), coordinates 56.5 × 94.6.
10. *Tetracolporopollenites* sp.; slide R4372O(1), coordinates 34.5 × 111.8.

11–16. Angiosperm pollen from the Nammal Formation of the Salt Range.

11. *Proxapertites operculatus* (van der Hammen 1954) van der Hammen 1956; slide R4379B(1), coordinates 50.0 × 107.5.
12. *Longapertites retipilatus* Kar 1985; slide R4379B(1), coordinates 54.9 × 95.2.
13. *Trilatiporites kutchensis* Venkatachala & Kar 1969; slide R4379D(1), coordinates 53.8 × 103.2.
14. *Tricolpites reticulatus* Couper 1953; slide R4379D(1), coordinates 53.8 × 103.2.
15. *Tricolpites* sp.; slide R4379D(1), coordinates 65.4 × 98.9.
16. *Cupuliferoipollenites* sp.; slide R4379K(1), coordinates 37.1 × 99.1.



Angiosperm Pollen from the Patala and Nammal Formations of the Salt Range