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PALYNOLOGY OF THE MESOZOIC SUCCESSION OF THE KALA CHITTA RANGE PAKISTAN

BY

KHAN RASS MASOOD, KALEEM AKHTER QURESHI
Department of Botany, University of the Punjab, Quaid-i-Azam Campus, Lahore 54590, Pakistan

AFTAB AHMAD BUTT AND SHAHID GHAZI
Institute of Geology, University of the Punjab, Quaid-i-Azam Campus, Lahore-54590 Pakistan

ABSTRACT:-*A total of one hundred six samples of the Mesozoic succession of the Kala Chitta Range were processed for the palynological analysis out of which only twenty one samples proved to be productive. Palynoflora recovered from the productive samples comprise thirty one form genera belonging to the thrity three form species. Eighteen triletes, two monoletes, eight bisaccates, two acritarchs and one monosaccates constitute eighteen genera. Palynoflora is less diverse exhibiting little compositional change. Lundbladispora willmotti and L. microconata are age diagnostic for the Upper Triassic Kingriali Formation. Aequitriradites triangulatus is typical of the Upper Jurassic-Lower Cretaceous Chichali Formation. Palynoflora are abundant in the Lower Cretaceous Lumshiwal Formation containing Succinctisporites grandior, Gordodinium alberti, Leptodineum eumorphum, Faveosporites subtriangularis, Densoisporites nejburji, Enzonalasporites vigens, Minutosaccus crenulatus, Ovalipollis ovalis, Podocarpites ellipticus and Aequitriradites triangulates. The Upper Cretaceous Kawagarh Formation contains Ptrospermella australliensis of Campanian age. The present contribution is the first comprehensive study of its kind.*

INTRODUCTION

The Kala Chitta Range is a part of the foreland-fold and thrust belt which forms the northern border of the adjoining hydrocarbon bearing Potwar Basin (Fig. 1). The sampled localities have been shown in Fig. 2. The abstract of this paper forms part of the abstract volume of the 33rd International Geological Congress, Oslo, Norway. (Butt et al. 2008).

The Mesozoic succession of the Kala Chitta Range as formalized by the Stratigraphic Committee of Pakistan (Fatmi, 1973) has been tabulated here as follows.

	Nomenclature of the Stratigraphic Committee of Pakistan (Fatmi 1977)	Nomenclature after Cotter (1933)
Upper Paleocene	Lockhart Limestone (Thanetian) Sequence Boundary (Absence of Maastrichtian-Danian)	Hill Limestone
Upper Cretaceous	Kawagarh Formation (Coniacian to Campanian) Sequence Boundary (Absence of Cenomanian-Turonian)	Kawagarh shales
Lower Cretaceous	Lumshiwal Formation	Giumal sandstone
Upper Jurassic-Lower Cretaceous	Chichali Formation Sequence Boundary (Lateritic Crust)	Spiti shale
Middle Jurassic	Samana Suk Limestone	Kioti Limestone
Lower Jurassic	Datta Formation	Ferruginous beds in the kiotos
Triassic	Kingriali Formation Chak Jabbi Limestone Mianwali Formation	Kioto Limestone

Base not exposed by virtue of the Thrust Fault

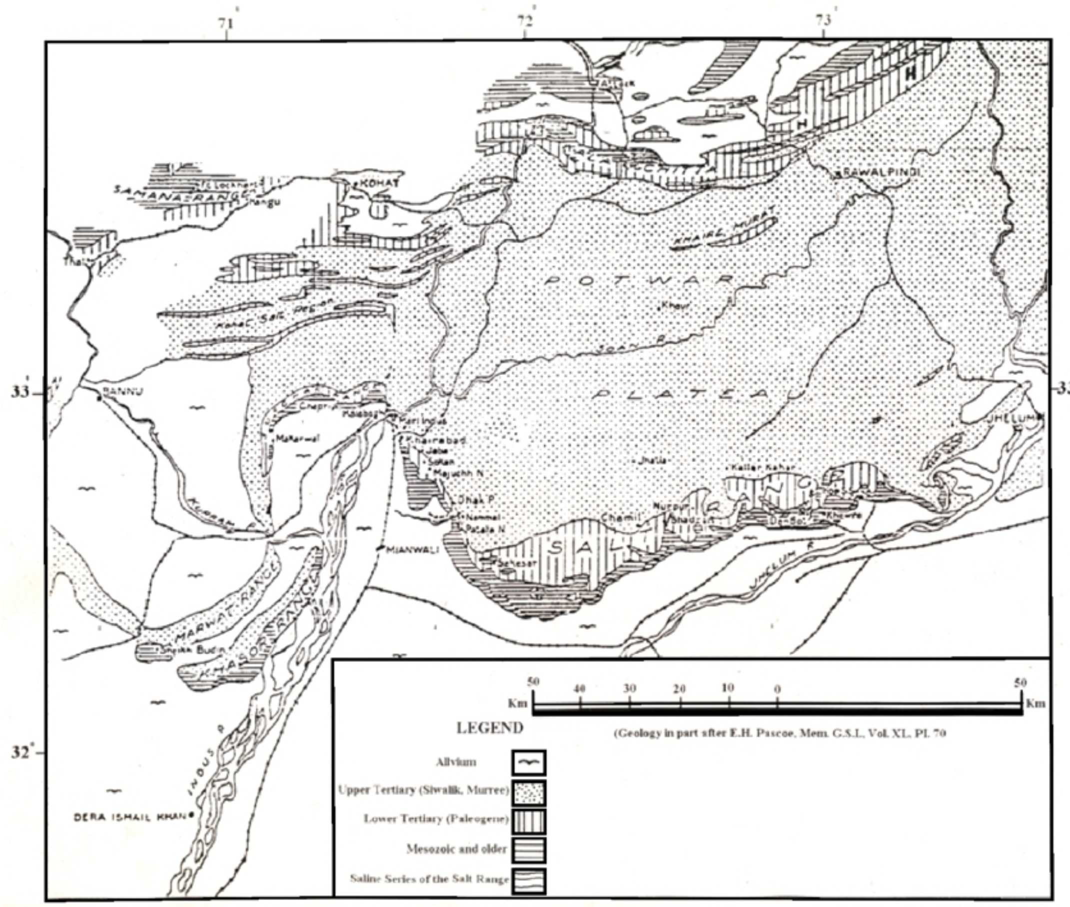


Fig. 1. Location map of the Kala Chitta and Samana Ranges (after Davies and Pinfold,1937)

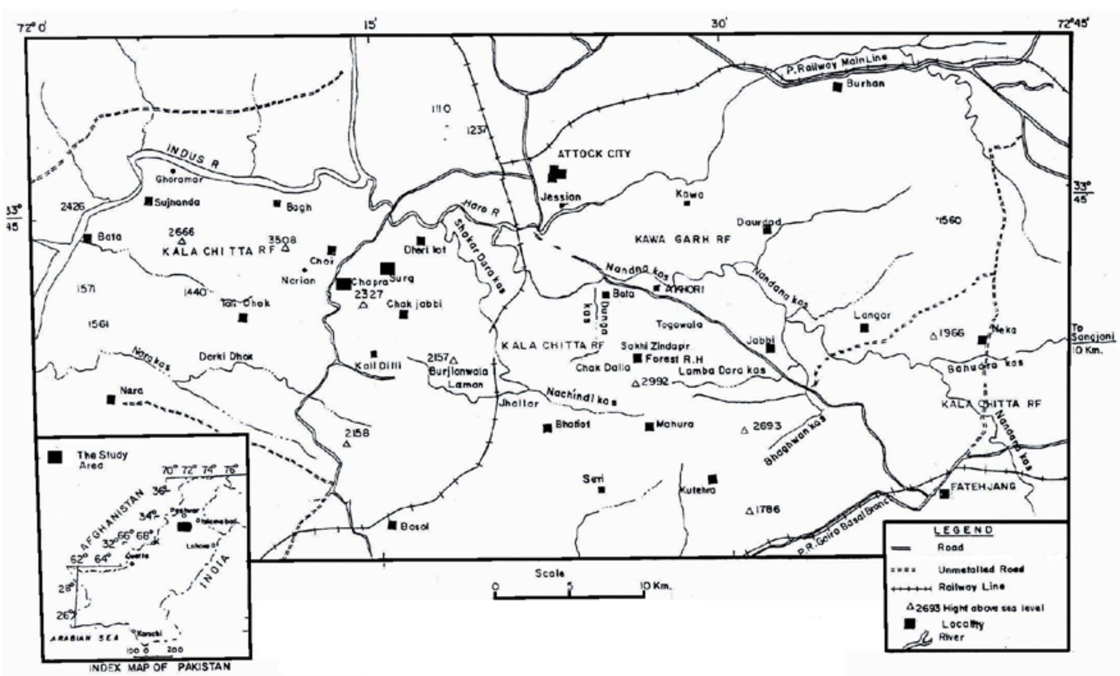


Fig. 2. Location map of the study area of Kala Chitta Range.

Palynomorphs are preserved in sediments under great variety of environments. During sedimentation they behave as very small particles like fine sand and silt. Coarse sandstones, oxidized and weathered sediments, dolomites and sometimes even limestones are poor containers of these microfossils. But some workers have reported well preserved palynomorphs in carbonate environments (Scott et al., 1985b; Masood et al., 1995, Blome and Albert, 1985).

Palynomorphs recovered during the present investigation are poorly preserved. In most cases it was difficult to apply correct identification beyond generic level. However, only those palynomorphs are included in this dissertation that were to some extant moderately preserved. Systematic section includes technical description of only selected palynomorphs most of which also appear in table No. 1.

A total of one hundred and six samples of the Mesozoic succession of the Kala Chitta Range were processed for palynological analysis. Only twenty one samples proved to be productive. The details are shown in table No. 1. It is quite evident from this table that the most productive samples belong to the Lumshiwal Formation, whereas, the Samana Suk Limestone and the Kingriali Formation were least productive.

METHODOLOGY

Special strew mount preparations were made (sandwich mounts between two cover slips) to allow morphographic examination of palynomorph from two angles i.e., proximal and distal. Descriptive features of each palynomorph species encompassing morphographic characters appearing in the systematic palynology were registered as they appeared in the actual specimen under oil immersion objective upon careful L-O analysis. Such features, however, may not be properly depicted in the photomicrographs provided due to poor state of preservation (e.g. crumpling, variously folding, differential decay).

REMARKS

Very few specimens allowed identification up to genus or species level. All palynomorphs posing problems regarding correct identification due to poor preservation were excluded from the study.

Palynoflora recovered from the productive samples comprise thirty one form genera belonging to thirty three form species. Of the thirty one genera 18 belong to triletes 2 to monoletes 8 to bisaccates 2 to acritarchs and one to monosaccates. Palynoflora is less diverse exhibiting little compositional change across the respective formation. Most miospores were of restricted origin, occurring only in one or two formations and very few long ranging types were encountered.

Consideration of Table No. 1 reveals that *Leiotriletes* and *Laevigatotriletes* are the only two long ranging genera occurring almost in all samples, whereas, *Alisporites grandis*, *Pinuspollenites sp.*, *Affropollis jordinus*, *Inaperturopollenites sp.* and *Pterospermella australiensis* were the next long ranging types commonly shared by two or more formations. *Punctatisporites* which otherwise is a long ranging form genus (Devonian to Neogene) was found to be restricted only to the basal part of the Lumshiwal Formation.

PALYNOSTRATIGRAPHY

Kingriali Formation (Upper Triassic)

The Kingriali Formation contains four palynospecies of restricted origin, viz., *Lundbladispora willmotti*, *L. microconata*, *Goubinispora sp.* and *Indotriletes korbaensis*. The first three are age diagnostic, mostly restricted to later part of the Middle Triassic (Jansonius and Hills, 1976).

Samana Suk Limestone (Middle Jurassic)

No age diagnostic or the palynomorph of restricted origin was found in this formation. Apart from the general long ranging types *Leiotriletes* and *Laevigatosporites* only few *Mycorrhizae* were found here.

Chichali Formation (Upper Jurassic-Lower Cretaceous)

This formation is slightly more productive than the Kingriali and the Samana Suk Formations. It contains *Leptolepidites eparcornatus* as the restricted form. *Impardecispora cf. parvelentus* (Plate No. 1c) may be another such type, but extending to the lower most part of the overlying Lumshiwal Formation. Age diagnostic palynomorphs for this formation are *Aequitriradites triangulatus* and *Frangospora sp.* that are peculiar for Early Cretaceous or some time Latest Jurassic (Jansonius and Hills, 1976).

Lumshiwal Formation (Lower Cretaceous)

The Lumshiwal Formation is palynologically the richest horizon investigated during the present study. Palynoflora recovered from this formation is most abundant and diverse as compared to other formations. *Punctatisporites sp.* (Plate No. 4e), *Succinctisporites grandior* (Plate No. 4a), *Gordodinium alberti* (Plate No. 4c), *Leptodineum eumorphum* (Plate No. 2e), *Foveosporites subtriangularis* (Plate No. 2f), *Densoisporites nejburji* (Plate No. 2a), *Enzonalasporites vigens* (Plate No. 4d), *Minutosaccus crenulatus* (Plate No.

Table 1
The frequency of occurrence of the palynomorphs in the Mesozoic sucession of the Kala Chitta Range.

AGE		TRIASSIC	JURASSIC		JURASSIC/ CRETACEOUS				C R E T A C E O U S													
FORMATION		KINGRIALI	SAMANA SUK		CHICHALI				LUMSHIWAL										KAWAGARH			
S.No	Sample No. PALYNOMORPH	576	703	1029	658	669	754	181	148	149	209	210	661	665	666	756	187	188	1236	1237	170	171
1	*Affropollis jordinus*												13.5	2		28		10	4	3.5		
2	*Densoisporites nejburgii*										10.5	15	6.5	1	13	4.5						
3	*Alisporites grandis*							8	5	8	4	10	3	3.5	9	19	21.5	4.5	8	1	2.5	2
4	*Alisporites bilateralis*							2	18	1.5	6.5	10.5	3.5	19	2.5	2.5	5	31	2	3.5	1	1
5	*Enzonalasporites vigens*								3	1.5	11						4.5					
6	*Frangospora sp.*							*51	1	1.5	1.5	9.5	2	16	10		21					
7	*Inaperturopollenites sp.*														1.5	2.5		3.5	2	1.5	1.3	
8	*Leptolepidites eparcornatus*				4.5	2.5	6	10														
9	*Leiotriletes sp.*		85	90	69	43	29	10	10	17	2.5	3.5	9.5	2	8.5	1.5	6	9	2.5	2	4	19
10	*Laevigatosporites sp.*		10	8	18	39	51	8	3	2	7	8.5	17	19	1	16	4	4.5	1	1	3	20
11	*Minutosaccus crenulatus*								2	3	4	4	8.5				5					
12	*Ovalipollis ovalis*								16	4.5	3.5						4					
13	*Podocarpites ellipticus*								8	5.5	1	2	7	16	8	2.5	1.5	19				
14	*Punctatisporites sp.*									28	11.5	6.5	2				1.5					
15	*Succinctisporites grandior*								12	2	9						4.5					
16	*Valiasaccites validus*													2	19	55		1.5				
17	*Leptodineum eumorphum*								2		13						9.5					

Table No. 1:Continued from pre-page.

S.No	Sample No. PALYNOMORPH	576	703	1029	658	669	754	181	148	149	209	210	661	665	666	756	187	88	1236	1237	170	171
18	*Gordodinium alberti*								9	2.5	2.5						2.5					
19	*Foveosporites subtriangularis*											18	8.5	1.5	1	11.5						
20	*Crybelosporites pannuceus*					7	4	3.5	1	3.5							3					
21	*Verrucosisporites narmianus*																		34	29		
22	*Verrucosisporites densus*																		20	14		
23	*Cyclobaculisporites minutus*																		15	23	56	49
24	*Inferopollenites sp.*																		5	4		
25	*Densipollenites densus*																		1.5	2	10	5
26	*Pinuspollenites sp.*								1.5	1	1.5	3	10	1.5	19	1.5	1	10	2	2.5	1	3
27	*Aequitriradites triangulatus*					4	5	2	1	2							1					
28	*Lundbladispora willmotti*	53																				
29	*Lundbladispora microconata*	2																				
30	*Indotriletes korbaensis*	34																				
31	*Impardecispora cf. parvelentus*				3.5	1	1.5	2.5	1.5													
32	*Pterospermella australiensis*																		3	12	9	
33	*Goubinispora sp.*	9.5																				
34	*Mycorrhiza*		4.5	2	4.5	1.5	1	1	2	4	6	7.5	1.5	13	4.5		1.5					
35	*Acritarchs*							1	4	3	1.5	1	1	1.5	1	3	1	5				
36	*Dinoflagellate*					2	1					1	2	1	2		1	0.5				
37	*Algal remnants*									1.5	2	1	2	1	1	1	1.5	0.5				

PLATE 1

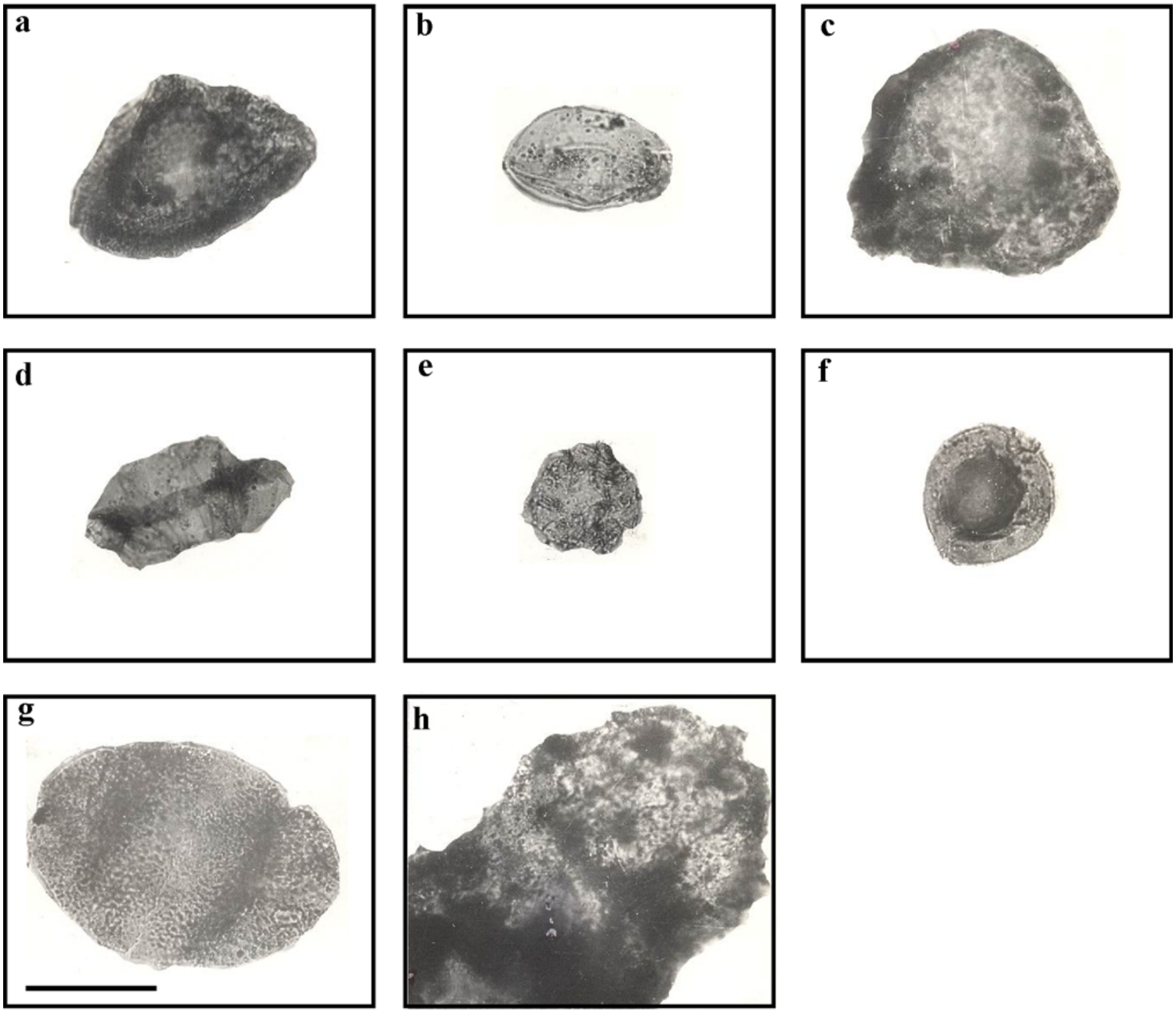


Fig. a *Aequitriradites triangulates*, Lumshiwal Formation. KQ. 188, Dheri Kot

Fig. b *Laevitriletes sp.,* Chichali Formation. KQ. 669, Burjianwala Laman

Fig. c *Impardecispora cf. parvelentus*, Chichali Formation. KQ. 754, Chapra

Fig. d *Bisaccate*, Lumshiwal Formation. KQ. 188, Dherikot

Fig. e *Indotriletes korbaensis*, Chichali Formation. KQ. 754, Chapra

Fig. f *Pterospermella australiensis*, Kawagarh Formation. KQ. 170, Choi

Fig. g *Alisporites grandis*, Chichali Formation. KQ. 669, Burjinwala Laman

Fig. h *Podocarpites sp.*, Chichali Formation. KQ. 754, Chapra

PLATE 2

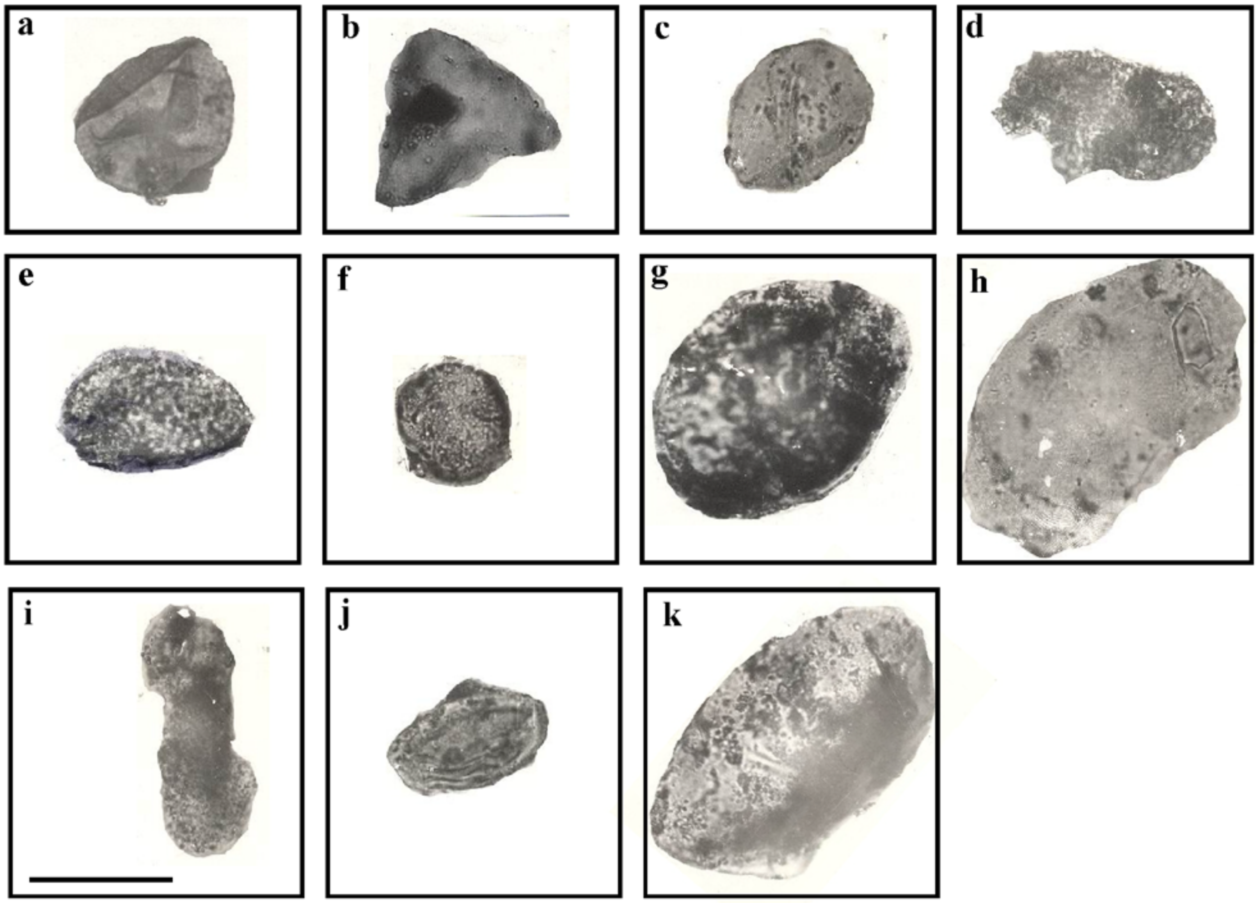


Fig. a *Densoisporites nejburji*, Lumshiwal Formation. KQ. 665, Burjianwala Laman

Fig. b *Leiotriletes sp.*, Lumshiwal Formation. KQ. 208, Daurdad

Fig. c *Leptolepidites eparcornatus*, Lumshiwal Formation. KQ. 187, Dherikot

Fig. d *Alisporites grandis*, Chichali Formation. KQ. 181, ½, F 2/7, Bata

Fig. e *Leptodineum eumorphum*, Lumshiwal Formation. KQ. 148, 6/3 F 3/24a, Togowala

Fig. f *Foveosporites subtriangularis*, Lumshiwal. KQ. 208, 1/1, F 1/35, Daurdad

Fig. g *Minutosaccus crenulatus*, Chichali Formation. KQ. 669, 4/1, F 3/2a, Burjianwala Laman

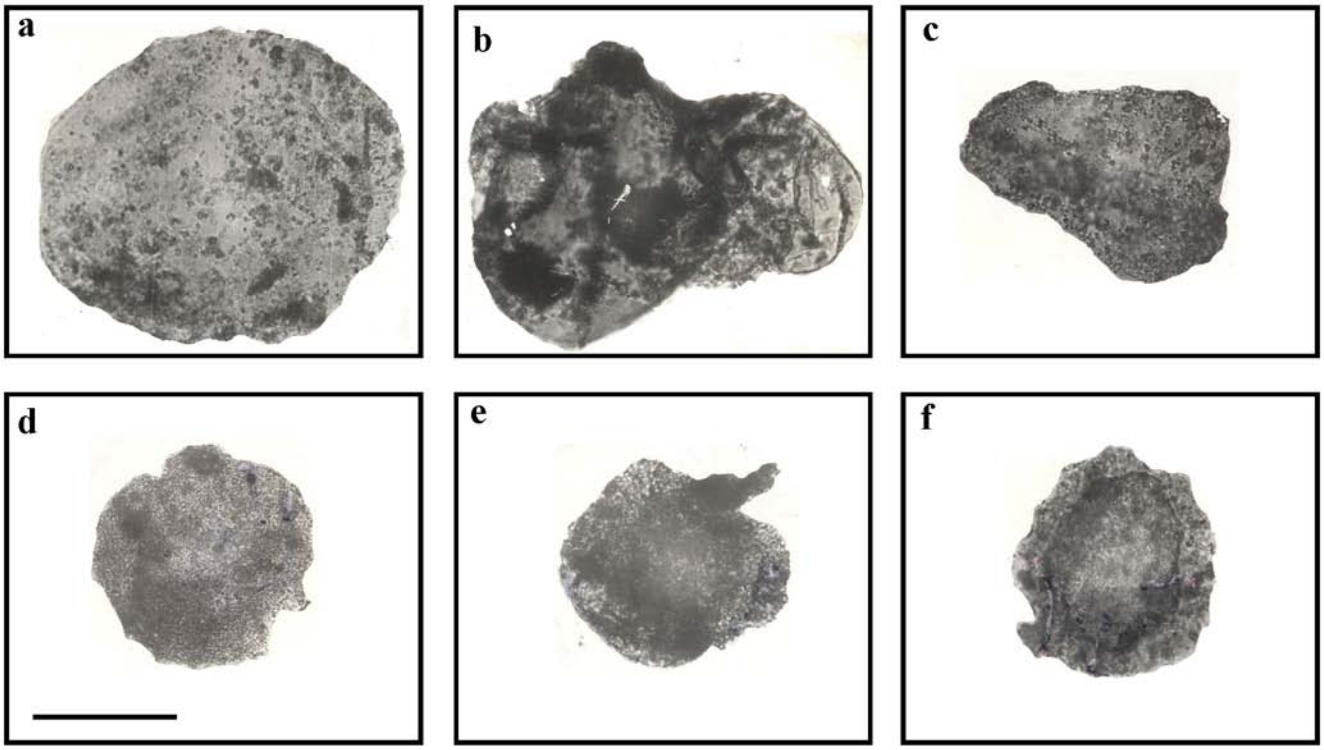
Fig. h *Alisporites bilateralis*, Chichali Formation. KQ. 181, 4/3, F 2/8, Bata

Fig. i *Valiasaccites validus*, Lumshiwal Formation. KQ. 147, 1/1, F 3/14, Togowala

Fig. j *Laevigatosporites sp.*, Lumshiwal Formation. KQ. 148, 3/3, F 3/20a, Togowala

Fig. k *Laevigatosporites sp.*, Lumshiwal Formation. KQ. 148, 6/3, F 3/23a, Togowala

PLATE 3



Lumshiwal Formation

Fig. a *Succinctisporites grandior*. KQ. 149, Togowala

Fig. b *Inaperturopollenites sp.* KQ. 148, Togowala

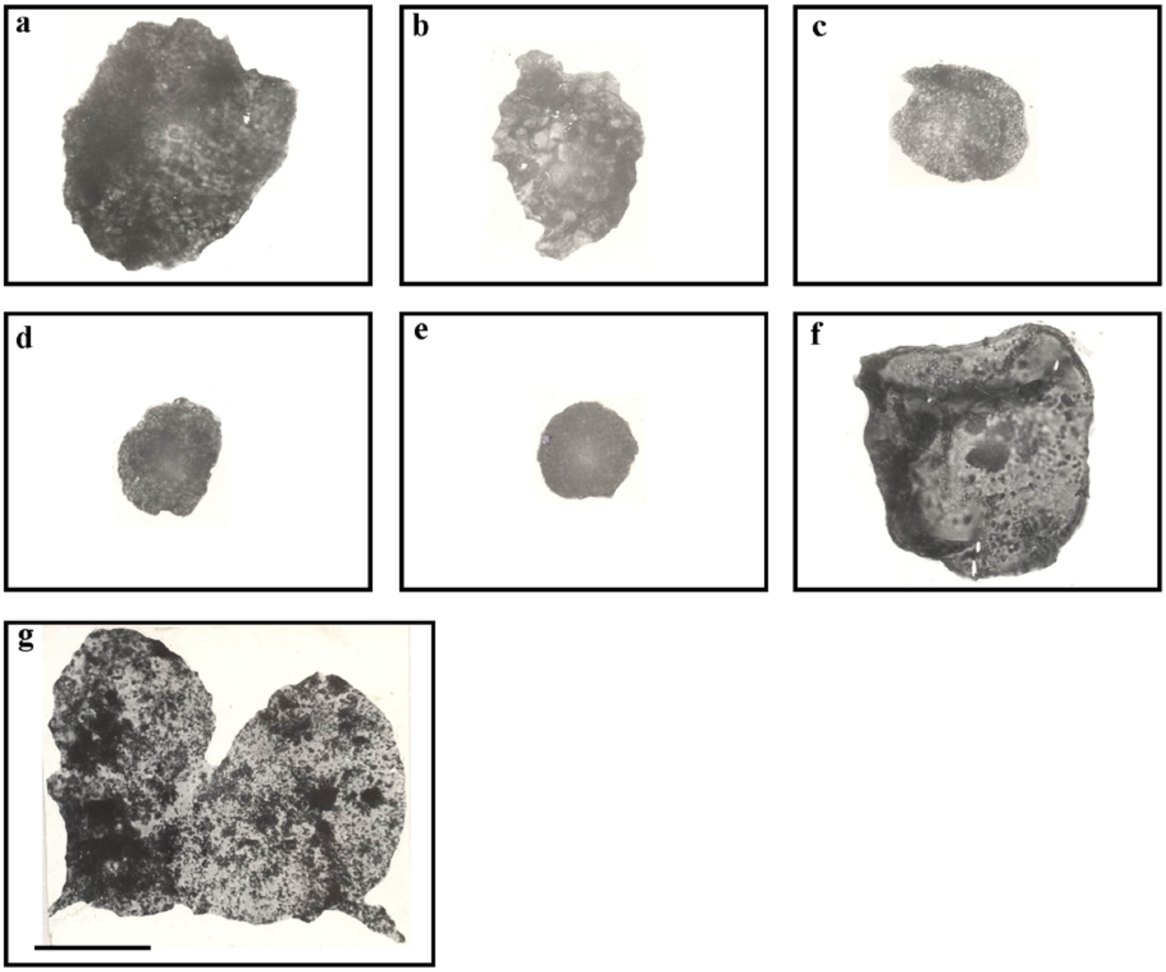
Fig. c *Ovalipolis ovalis.* KQ. 149, Togowala

Fig. d *Crybelosporites sp.* KQ. 209, Daurdad

Fig. e *Crybelosporites pannuceus.* KQ. 149, Togowala

Fig. f *Afropollis jardinus.* KQ. 756, Chapra

PLATE 4



Lumshiwal Formation

Fig. a *Podocarpites ellipticus*. KQ. 148, Togowala

Fig. b *Palambages sp*. KQ. 149, Togowala

Fig. c *Gordodinium alberti*. KQ. 149, Togowala

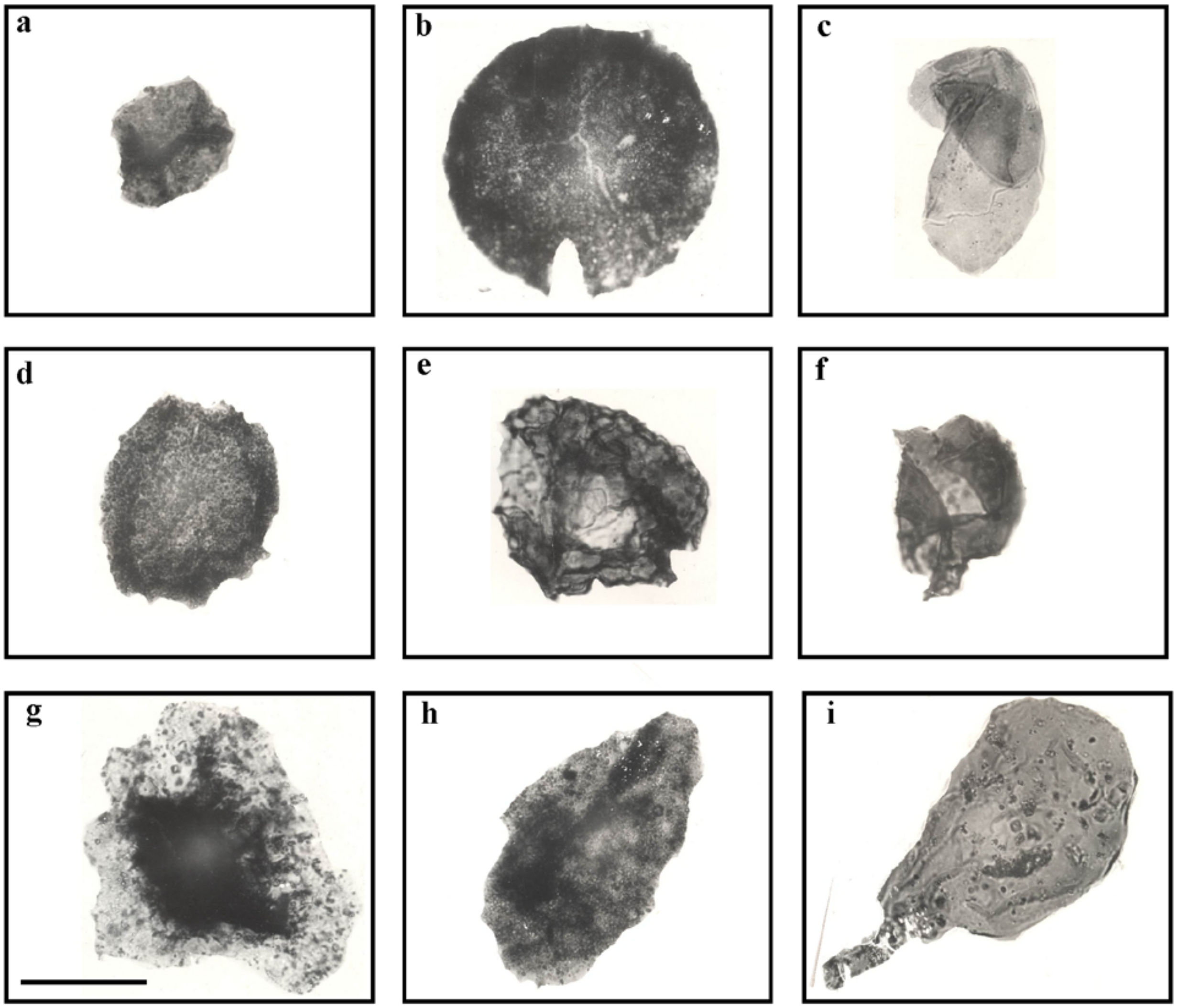
Fig. d *Enzonalasporites vigens*. KQ. 148, Togowala

Fig. e *Punctatisporites sp*. KQ. 149, Togowala

Fig. f *Frangospora sp*. KQ. 148, Togowala

Fig. g *Endogone sp*. KQ. 149, Togowala

PLATE 5



Kawargarh Formation

Fig. a *Cyclobaculisporites minutes.* KQ. 170, Choi

Fig. b *Verrucosisporites narmianus.* KQ. 1236, Surg

Fig. c *Pinuspollenites sp.* KQ.1225, Dherikot

Fig. d *Verrucosisporites densus.* KQ. 170, Choi

Fig. e *Palambages sp. (Acritarch).* KQ. 1237, Surg

Fig. f *Leiotriletes sp.* KQ. 170, Choi

Fig. g *Densipollenites densus.* KQ. 1237, Surg

Fig. h *Infernopollenites sp.* Kq. 170, Choi

Fig. i *Sclerocystis sp.* KQ. 158, Daurdad

2g), *Ovalipollis ovalis* (Plate No. 3c) and *Podocarpites ellipticus* (Plate No. 4a) are of restricted origin, whereas, *Frangospora sp.* (Plate No. 4f) and *Aequitriradites triangulatus* (Plate No. 1a) are age diagnostic.

Kawagarh Formation (Late Cretaceous)

Kawagarh Formation was poorly productive. Apart from *Leiotriletes* and *Laevigatotriletes* that are the general long ranging types for all the formations only four palynomorphs species are encountered here. These are also commonly shared by the Lumshiwal Formation, viz., *Affropollis jordinus* (Plate No. 3f), *Alisporites grandis*, *Inaperturopollenites sp.* (Plate No. 3b) and *Pinuspollenites sp.* (Plate No. 5c). Apart from these commonly shared types, the Kawagarh Formation also contains *Ptrospermella australiensis* (Plate No. 1f) that is age diagnostic for Campanian.

Considerations of table No. 3 reveal that three palynomorph genera (recovered during the present study) deviate considerably from their already established stratigraphical range of occurrence. *Leptolepidites* was found in the Lumshiwal Formation (Lower Cretaceous) which otherwise is only restricted to the Jurassic strata. *Densipollenites* has a restricted range of occurrence between Early Permian to Late Jurassic, but in the Kala Chitta Range it was identified in the Kawagarh Formation (Upper Cretaceous), whereas, *Lundbladispora* (purely a Triassic genus) was also isolated from the Samana Suk Limestone (Middle Jurassic). All these exceptions might be due to the reworking/stratigraphical leak or the contamination of the palynomorphs. If further studies reconfirm such instances in the same outcrops of adjoining areas, the stratigraphical occurrences of these genera (*Leptolepidites Densipollenites*, *Lundbladispora*) might be revised.

SYSTEMATIC PALYNOLOGY

Anteturma SPORITES H. Potonie, 1893
Turma TRILETES (Reinsch) Dettmann, 1963
Suprasubturma ACAVATITRILETES Dettmann, 1963
Subturma AZONOTRILETES (Luber) Dettmann, 1963
Genus *Leiotriletes* Naumova ex Isohchenko 1952
Type species *Leiotriletes sphaerotriangulatus* (Loose) Potonie and Kreump 1954
Leiotriletes sp.
Plate No. 2b, Plate No. 5f

Description: Miospore, trilete, amb triangular or subrounded, distorted due to compression, "Y" marking not very clear, longer than ½ radius. Exine faintly infrapunctate, up to 1 µm.

Genus *Punctatisporites* Ibrahim 1933
Type species *Punctatisporites punctatus* (Ibrahim) Ibrahim 1933
Punctatisporites sp.
Plate No. 4e

Description: Miospore, trilete, amb ± circular, trilete rays relatively short, may or may not be reaching equator. Exine punctate or finely reticulate up to 1 µm thick.

Genus *Frangospora* Venkatachala and Kar 1968
Type species *Frangospora fracta* Venkatachala and Kar
Frangospora fracta Venkatachala and Kar
Plate No. 4f

Description: Miospore, trilete, amb circular to subcircular rays ¾ radius, tapering, exine laevigate, sometimes infra-structured, unevenly thickened, outer exine splitting up by irregularly distributed cleavages giving the spore a mud crack like appearance, exine 2 µm.

Genus *Foveosporites* Balme 1957
Type species *Foveosporites canalis* Balme 1957
Foveosporites subtriangularis (Brenner) Doring
Plate No. 2f

Description: Miospore, trilete, amb rounded or elongate triangular, angles broadly rounded sides straight to convex. "Y" marking extending ¾ radius. Exine infraverrucate to foveolate ± 3 µm thick.

Genus *Verrucosisporites* Ibrahim, 1933
Type species *Verrucosisporites verrucosus* Ibrahim
Verrucosisporites narmianus Balme, 1970
Plate No. 5b

Description: Miospore, trilete, amb circular to subcircular, exine verrucose, verrucae closely set, height equal to or less than their breadth, apex truncate, average diameter of verrucae 3-4 µm, exine up to 3 µm thick.

Genus *Leptolepidites* Couper, 1953
Type species *Leptolepidites verrucatus* Couper
Leptolepidites eparcornatus
Plate No. 2c

Description: Miospore, trilete, amb subtriangular, sides convex to concave, biconvex in equatorial view. "Y" marking usually well developed, but not discernable in present specimen due to poor preservation. Exine very thick (up to 3 µm). Sculptured with large irregularly shaped rounded verrucae.

Table 2

Relationship between various chemical compounds and palynomorph occurrence in the Mesozoic sucession of the Kala Chitta Range.

Age	Formation	Sample	SiO_2	Fe_2O_3	FeO	P_2O_5	TiO_2	Al_2O_3	CaO	MgO	MnO	Na_2O	K_2O	H_2O^+	H_2O^-	CO_2	S	C	Total	Pal/g
Triassi c	Kingriali	576	0.48	1.55	1.18	-	0.15	0.80	42.62	8.06	0.04	1.54	1.25	0.10	0.20	41.74	0.24	0.10	99.99	164
	Samana	703	3.91	1.13	0.42	4.41	3.02	0.47	43.88	0.20	0.04	2.45	1.28	0.10	0.02	35.59	0.87	2.21	100	1050
Jurassic	Suk	1029	10.92	1.59	0.16	0.04	0.30	0.37	28.04	16.13	0.04	1.62	0.68	0.10	0.12	37.62	0.06	2.21	100	54
		658	50.70	1.04	0.12	0.02	0.30	6.63	20.50	2.94	0.07	1.65	0.68	0.10	0.09	14.61	0.15	0.40	100	800
Jurassic /		669	16.22	4.82	0.10	0.80	0.20	6.98	35.89	2.42	0.01	0.21	0.26	0.10	0.09	31.73	0.06	0.10	99.99	482
Creta-ceous	Chichali	754	34.74	1.30	0.42	0.02	0.30	7.69	30.44	5.53	0.04	1.35	0.50	0.10	0.10	17.26	0.29	0.10	100	150
		148	28.74	0.30	0.02	0.02	0.30	6.59	36.44	0.35	0.04	1.35	0.50	0.10	0.10	23.20	0.29	0.10	98.56	4080
		149	44.67	1.09	0.24	0.02	0.30	8.08	21.86	1.81	0.05	2.45	1.28	0.10	0.13	17.77	0.06	0.10	100	2400
		187	15.04	2.79	0.10	1.91	0.10	8.43	38.13	2.36	0.02	0.86	0.23	1.51	0.62	26.26	0.15	1.30	99.99	1000
		188	47.40	8.16	2.42	0.05	1.50	8.99	12.33	1.61	0.04	1.53	1.96	0.10	3.30	10.30	0.19	0.10	99.98	9000
Lower	Lumshiwal	209	20.42	5.71	0.44	0.09	0.42	9.83	33.94	5.91	0.09	1.53	3.01	0.10	2.00	16.35	0.06	0.10	100	6200
		210	14.61	9.00	2.78	0.17	0.97	12.58	39.11	3.22	0.01	3.45	4.20	1.68	1.29	6.17	0.03	0.20	99.52	10100
		661	45.19	5.15	0.32	0.09	0.20	1.33	21.16	1.35	0.06	2.22	2.41	0.10	3.30	16.90	0.04	0.20	100	8000
		665	29.00	1.30	0.32	0.02	0.30	5.69	28.00	5.60	0.04	1.32	0.06	0.10	0.20	27.10	0.26	0.10	99.94	2000
		666	20.20	1.23	0.32	0.09	0.08	5.20	33.25	2.31	0.06	1.35	0.68	0.10	0.08	33.31	0.06	0.10	98.42	4200
Creta-ceous		756	9.33	0.09	1.80	0.11	0.71	10.15	48.82	6.15	0.05	3.36	3.89	0.93	2.92	6.62	0.20	2.21	99.34	7100
		170	24.70	1.30	0.42	0.01	0.20	2.69	38.45	6.35	0.04	2.17	2.56	0.10	0.32	19.30	0.07	1.30	99.98	400
		171	16.74	1.24	0.10	0.02	0.38	1.24	40.72	2.97	0.06	2.22	2.65	0.10	0.14	30.41	0.87	1.30	100	192
Upper		1236	20.15	3.25	2.17	0.05	0.20	4.30	35.77	1.64	0.02	2.11	2.71	0.10	0.11	27.02	0.16	0.20	99.96	1000
Creta-ceous	Kawagarh	1237	18.20	2.20	0.17	0.04	0.20	4.60	38.40	2.02	0.04	2.05	1.51	0.10	0.13	30.08	0.06	0.20	100	984
r-values			+0.39	+0.66	+0.60	-0.22	+0.24	+0.56	-0.02	-0.23	-0.20	+0.50	+0.61	+0.11	+0.83	-0.70	-0.30	-0.20		
(Co-efficient of correlation)			ns	**	**	ns	ns	**	ns	ns	ns	*	**	ns	**	**	ns	ns	-	-

Legend: ns= not significant at α 0.05 Pal/g = Palynomorph per gram of sample
*= significant at α 0.05
**= highly significant at α 0.05 (significant at α 0.01)

Table 3

Tentative range of occurrence of some stratigraphically important palynomorph genera recovered from the Mesozoic Rocks of the Kala Chitta Range.

AGE		TRIASSIC			JURASSIC			CRETACEOUS		
S. No	Genus	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
1	*Affropollis*							—	—	
2	*Densoisporites*			■ ■ ■	—	—	—	—	—	—
3	*Alisporites*	« —	—	—			—	—	—	— »
4	*Frangospora*				—	—	—	—	—	—
5	*Inaperturopollenites*									— »
6	*Leptolepidites*				—	—	—			
7	*Leiotriletes*	« —	—	—	—	—	—	—	—	— »
8	*Laevigatosporites*	—	—	—	—	—	—	—	—	—
9	*Minutosaccus*	—	—	—				—	—	—
10	*Ovalipollis*							—	—	—
11	*Podocarpites*	—	—	—	—	—	—	—	—	—
12	*Punctatisporites*	—	—	—	—	—	—	—	—	—
13	*Succinctisporites*			■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
14	*Valiasaccites*	—	—	—	—	—	—	—	—	—
15	*Foveosporites*	—	—	—	—	—	—	—	—	—
16	*Crybelosporites*	—	—	—	—	—	—	—	—	—
17	*Verrucosisporites*	—	—	—	■ ■ ■	■ ■ ■	■ ■ ■	—	—	—
18	*Cyclobaculisporites*	—	—	—	■ ■ ■	■ ■ ■	■ ■ ■	—	—	—
19	*Inferopollenites*			—	■ ■ ■	■ ■ ■	■ ■ ■	—	—	—
20	*Densipollenites*	—	—	—	—	—	—			
21	*Pinuspollenites*	—	—	—	—	—	—	—	—	—
22	*Aequitriradites*				—	—	—	—	—	—
23	*Lundbladispora*	—	—	—						
24	*Pterospermella*							—	—	—
25	*Goubinispora*	—	—	—						

■ ■ ■ ■ ■ Age not clearly established.

« Extending into older rocks

» Extending into younger rocks

Subinfraturma NODATI Dybova and Jackovicz (1957)
Genus *Cyclobaculisporites* Bharadwaj 1955

Type species *Cyclobaculisporites grandiverrucosus* (Kosanke) Bharadwaj

Cyclobaculisporites minutus Kar 1968
Plate No. 5a

Description: Miospore, trilete, amb circular to subcircular, trilete rays indistinct, less than _ radius, exine surface thickly set with baculae of uniform length but widely ranging width, interbacular spaces very narrow, discernable only under oil immersion objective.

Infraturma CINGULATI (Potonie and Klaus) Dettmann, 1963
Genus *Densoisporites* Weyland and Krieger, 1953
Type species *Densoisporites velatus* Weyland and Krieger
Densoisporites nejburgii (Schulze) Balme
Plate No. 2a

Description: Miospore, trilete, amb rounded, triangular, "Y" mark distinct, rays extending to or into the flange, with narrow raised lips fading towards equator. Exine up to 2 µm thick, with surface finely granulate to chagrenate. The exoexine is proximally and distally ± tightly fitting, but equatorially cavate and sculptured by numerous short plications and wrinkles.

Genus *Crybelosporites* Dettmann 1963
Type species *Crybelosporites striatus* (Cookson and Dettmann) Dettmann
Crybelosporites pannuceus (Brenner) Srivestava
Plate No. 3e

Description: Miospore, trilete, amb spheroidal to ellipsoidal, exine stratified consisting of a smooth homogenous inner layer enclosed within a two layered, proximally cavate, structured 'sculptine', outer layer of sculptine without a trilete aperture, proximally detached from trilete, inner layers; and with a reticulate, rugulate, or foveolate (OL) surface pattern.

Genus *Lundbladispora* Balme 1963
Type species *Lundbladispora willmotti* Balme
Lundbladispora willmotti Balme

Description: Miospore, trilete, amb subcircular to subtriangular, exine cavate, a finely structured exoexine enclosing a thin walled intexine, "Y" marking usually well developed.

Turma MONOLETES Ibrahim 1933
Suprasubturma ACAVATOMONOLETES Dettmann, 1963
Subturma AZONOMONOLETES Luber, 1935
Genus *Laevigatosporites* Ibrahim, 1933
Type species *Laevigatosporites vulgaris* Ibrahim
Laevigatosporites sp.
Plate No. 2j, k

Description: Miospore, monolete, amb broadly oval, tetrad scar distinct, alete extending ¾ length of spore, commissure thin, bordered by distinct labra. Exine up to 3 µm thick, laevigate to chagrenate.

Turma ALETES Ibrahim
Genus *Inaperturopollenites* Pflug in Thomson and Pflug 1953
Type species *Inaperturopollenites dubius* (Potonie and Venkatachala) Thomson and Pflug 1953
Inaperturopollenites sp.
Plate No. 3b

Description: Pollen grain, germinal apparatus or suture indistinct, amb circular or subcircular. Exine thin up to 1 µm thick, infrapunctate with many secondary folds.

Anteturma POLLENITES Potonie 1931
Turma SACCITES Erdtman 1947
Subturma MONOSACCITES (Chitaley) Potonie and Kremp 1954
Genus *Enzonalasporites* Leschik 1956a
Type Species *Enzonalasporites vigens* Leschik
Enzonalasporites vigens Leschik
Plate No. 4d

Description:- Pollen grain, monosaccate, overall amb circular, corpus circular to sub circular not very well demarcated due to the poor state of preservation in the given specimen, exine of corpus rugulose, alete, velum not very sharply differentiated from central body.

Genus *Goubinispora*
Type species *Goubinispora*
Goubinispora sp.

Description: Pollen grain, monosaccate, central body diffuse, not sharply delineated, alete, saccus slightly lobed, exoexine of saccus infrareticulate, up to 2µm thick.

Subturma DISACCITES Cooksoon, 1947
Infraturma STRIATITI Pant, 1954
Genus *Infernopollenites* Scheuring 1970
Type species *Infernopollenites sulcatus* Scheuring
Infernopollenites sp.
Plate No. 5h

Description:- Pollen grain, bisaccate, diploxylonoid, central body circular to subcircular, usually three broad longitudinal taeniae that usually are closely joined or are separated by narrow ectexinal fissures covering the proximal hemisphere are characteristic for this genus, but these are not sharply delineated here due to bad state of preservation. Distal bases of sacci are straight. Exine of corpus infrapunctate up to 1.5 µm thick. Exoexine of sacci 2 µm.

Non Taeniate Bisaccate

Genus *Pinuspollenites* Raatz 1938, Potonie 1958
Type species *Pinuspollenites labdacus* (Potonie) Raatz ex Potonie 1958
Pinuspollenites sp.
Plate No. 5c

Description:**-** Pollen grain, bisaccate, slightly diploxylonoid, corpus circular to subcircular, without germinal suture, exine of corpus laevigate up to 1.5 µm thick. Sacci small, attachment ventral , exoexine of sacci 2 µm thick.

Genus *Valiasaccites* Bose and Kar 1966
Type species *Valiasaccites validus* Bose and Kar
Valiasaccites validus Bose & Kar
Plate No. 2i

Description:**-** Pollen grain, bisaccate, haploxylonoid, overall amb ± oval, central body oval, usually with two longitudinal lateral ridges which are not detectable in the present specimen. Exine of corpus infravermiculate to infrareticulate. Monolete mark on corpus absent. Proximal saccus attachment zone along equator, distally subequatorial and associated with a semilunar body. Sacci semicircular, coarsely intrareticulate (makes up to 2 µm), attachment of sacci lateral with slight ventral displacement. Exoexine of sacci up to 2 µm thick.

Genus *Podocarpites* Bolkhovitina 1956
Type species *Podocarpites flacciformis* (Malj.) ex Bolkhovitina
Podocarpites sp.
Plate No. 1h

Description:**-** Pollen grain, bisaccate haploxylonoid to slightly diploxylonoid. Central body circular to subcircular, alete. Exine of corpus infrapunctate up to 1.5 µm thick. Attachment of sacci lateral with slight ventral displacement. Exoexine of sacci up to 2 µm thick.

Genus *Ovalipollis* Krutrch 1955
Type species *Ovalipollis ovalis* Krutrch
Ovalipolis ovalis Krutrch
Plate No. 3c

Description:**-** Pollen grain, bisaccate, overall amb slender or broadly oval, in part rhombic, usually a major fold runs longitudinally on one face from one end to other, the pointed ends of oval central body are capped by weakly developed sacci that possess a pronounced rodlet structure and have a smooth surface. Exine of central body up to 1.5 µm thick whereas that of sacci up to 2 µm thick.

Genus *Minutosaccus* Madler 1964
Type species *Minutosaccus acutus* Madler 1984
Minutosaccus crenulatus Dobly
Plate No. 2g

Description:**-** Pollen grain, bisaccate, haploxylonoid, overall amb broadly fusiform, central body circular to subcircular, strongly cutinized and small, sacci distally displaced, usually with sharply delineated sulcus which is detectable in actual specimen under oil immersion objective upon careful L-O analysis but not in the photomicrograph provided. Exine of corpus laevigate up to 2 µm thick, exoexine of sacci up to 1.5 µm thick.

Genus *Alisporites* Daugherty emend Nilsson, 1958
Type Species *Alisporites opii* Daugherty
Alisporites grandis (Cookson) Dettman
Plate No. 1g

Description:**-** Pollen grain, bisaccate, haploxylonoid, central body circular to subcircular. Exine of corpus 1 µm thick laevigate. Sacci attached laterally with slight distal inclination. Exoexine of sacci infra reticulate up to 1.5 µm thick.

Non-Vesiculate Tectate Pollen

Genus *Afropollis* Doyle, Jardine and Doerenkamp 1982
Type species *Afropollis Jardina* (Brenner) Doyle
Afropollis jardina (Brenner) Doyle
Plate No. 3f

Description:**-** Pollen grain, overall amb spheroidal, radially symmetrical, coarsely reticulate to ruguloreticulate, semitectate. Due to corrosion and poor preservation, differentiation of tectum is not so sharp in the photomicrograph provided. It was however, discernable under oil immersion objective upon careful L-O analysis in the actual specimen. Lumina on most of the grain surface 2-5 µm maximum dimension.

GEOCHEMISTRY AND PALYNOMORPH PRODUCTIVITY

During the present study an attempt has been made to investigate whether or not the chemical composition (or any change in it) of the parent sediment affects productivity and preservation of palynomorphs in the Mesozoic rocks of the Kala Chitta Range. However, if a particular sediment is not productive (containing no palynomorphs) no method is devised to date to judge whether it originally contained palynomorphs or not, or the microfossils disappeared later due to some postdepostitional hazard(s). The author has personally observed that if a zone of a particular formation is highly productive at one level, it may become poorly productive or totally barren at another horizon. As indicated by several workers it may be due to the changes in depositional environments (Darrell and Hart, 1979), thermal effects (Dow, 1977) or other post depositional hazards (Bonny, 1976, 1978).

Some other sedimentological factors in combination with the associated vegetational pattern on nearby land and the differential rate of transportation of various palynomorphs to the depositional site may affect occurrence and preservation of palynoflora in rocks (Smith, 1962; Chaloner and Muir, 1968; Phillips et al., 1974; Scott and King, 1981). But the possibility of the fact that any change(s) in the chemical composition of the parent sediment may affect palynomorph productivity cannot be ruled out totally.

Twenty rock samples viz KQ 575 (Kingriali Formation); KQ 703, KQ 1029 (Samana Suk Limestone); KQ 658, KQ 669, KQ 754 (Chichali Formation); KQ 148, KQ 149, KQ 187, KQ 188, KQ 209, KQ 210, KQ 661, KQ 665, KQ 666, KQ 756 (Lumshiwal Formation); KQ 1236, KQ 1237, KQ 170, KQ 171 (Kawagarh Formation) were randomly selected to study such phenomenon.

Chemical analysis

The contents of SiO_2, H_2O+, H_2O- were determined gravimetrically. Al_2O_3, MnO, CaO and MgO were determined by atomic absorption and spectrophotometry.

The amounts of TiO_2 and P_2O_5 were determined by spectrophotometry. FeO and inorganic carbon were determined volumetrically. The alkalies and organic carbon were determined by C and S analyser.

Statistical analysis

Coefficient of correlation (r-values) were calculated between percentages of an elemental oxide and number of palynomorphs/g in different samples to check whether any relationship exists between the two independent variables viz: percentage of an elemental oxide and number of polynomorphs per gram of samples (productivity).

Table No. 2 shows the sample wise percentage of elemental oxides and number of palynomorphs/g of different samples and the r-values.

It has been observed that FeO, Fe_2O_3, Al_2O_3, K_2O show highly significant positive correlation between the two independent variables indicating a highly favourable chemical environment for palynomorph preservability. Na_2O also shows significant positive correlation. Negative correlation is also observed in P_2O_5, CaO, MgO, MnO, though not significant at 5% level of significance. However, it may indicate that oxidizing environments such as that of P_2O_5 are highly unfavourable for palynomorph preservation. Similarly, CaO and MgO, which are components of dolomites, are also unsuitable for palynomorph preservability. Similar observations have also been made by Masood et al. (1995) on the samples from the Amb Formation (Permian) of the Salt Range.

The above study indicates that the higher amounts of FeO, Fe_2O_3, Al_2O_3, K_2O, Na_2O, SiO_2 TiO_2 favour higher palynomorph occurrence whereas P_2O_5, CaO, MgO and MnO_2 impart low productivity.

PALEOCLIMATOLOGY AND DEPOSITIONAL ENVIRONMENTS

The climate experienced by an area at a particular time depends upon its continentality and latitudinal position. Fossil spores and pollen exhibit various morphographic characters with specific configurations and structures, each with a precise function. These morphographic features transcend taxonomic delimitations of the dispersed spores and pollen. The behaviour pattern of significant morphographic events are evaluated for their sensitivity to climate. The combination of characters in a given palynoflora is diagnostic for that period and it has been considered for climatic interpretation. Since the palynoflora recovered during the present investigation was not well preserved, it was not possible in most cases to interpret morphographic features associated with palynomorphs correctly, and hence accurate climatic interpretation at various stratigraphic levels was not possible.

Considering Bharadwaj scheme (1966) it is possible to some extent to comment on vegetational history and then to elucidate the depositional environment on a broad scale. According to Bharadwaj scheme -- trilete and monolete miospores represent Cryptogams striated bisaccates, Glossopteroids; non-striated bisaccates, Conifers, trilete monosaccates, Gangamopteroids, monosulcates, Cycadoginkops and alete monosaccates represent Cordaitales.

Absence of monosaccate in all samples except in the Kingriali Formation (i.e. *Goubinispora*) is noteworthy (Table No. 1), indicating that none of the members of *Pteridospermaeles* existed within the close vicinity of the depositional site from Jurassic to Upper Cretaceous periods.

CONCLUSION

Assemblages from Kingriali Formation, the Samana Suk Limestone and the Chichali Formations are characterised by poor preservation, lack of diversity and the presence of enormous small spinose acritarch and indistinctive leiospheres. The Kingriali Formation also contains few species of *Lundbladispora* and *Goubinispora*. Both these types indicate tropical to subtropical hot climate with medium to high humidity in closely located land area, whereas, the palynoflora of the Samana Suk Limestone and the Chichali Formation include great abundance of cryptogams, which must be present very near to shore in an upland area with typical temperate to subtemperate (low cooling) with medium to high humidity.

Assemblages of the Lumshiwal Formation are much more diverse than those recovered from any other formation. The distributional heterogeneity is evident from consideration of Table 1. Several pollen species were found only in the Lumshiwal Formation and the diversification of spore and pollen assemblage is due mainly to an increase in the variety of trilete and bisaccate palynomorphs.

Taken in its entirety a strongly regressive phase, which may of course have been associated with wide climatic changes, have been observed. Regression would be expected to manifest itself by an increase in the number of plant microfossils reaching the depositional area. A decrease in the number and veriety of the acritarchs and the diversification of the assemblages associated with large number of pollen and spores derived from subordinate or locally restricted floral elements are the characteristics of the assemblages from the Lumshiwal Formation.

There is a marked decline in this trend in the Kawagarh Formation. However, the Kawagarh Formation is palynologically more rich as compared to the Kingriali Formation or the Samana Suk Limestone.

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