Supplemental Information

Multiproxy synthesis at the Arlington Archosaur Site: New insights into Cretaceous paralic paleoenvironments and regional stratigraphy, Woodbine Group, Texas, USA.

Christopher R. Noto[1], Peter P. Flaig[2], and Maria Antonieta Lorente[3]

[1] Department of Biological Sciences, University of Wisconsin–Parkside, 900 Wood Rd PO Box 2000, Kenosha, Wisconsin 53141, U.S.A.
[2] Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin, 10100 Burnet Rd., Bldg. 130, Austin, Texas 78758-4445, U.S.A.
[3] Geology, Central University Venezuela and Ellington Geological Services, 1414 Lumpkin Rd., Houston, Texas 77043, U.S.A.

Author Note

Christopher Noto	https://orcid.org/0000-0003-1829-2593
Peter Flaig	https://orcid.org/0000-0002-4702-2157
Maria Antonieta Lorente	https://orcid.org/0000-0002-2191-7729

Correspondence concerning this article should be addressed to Christopher Noto, email: noto@uwp.edu

Table Contents **Page**

SUPPLEMENT 1: Palynology Methodology

Samples were prepared following traditional acid palynological techniques using hydrochloric acid (10% HCl) and hydrofluoric acid (70% HF) maceration to dissolve carbonate and siliceous contents. The organic fraction was separated using centrifugation in a heavy liquid ($ZnBr_2$ □ H_20). A Schultz solution was applied before sieving the final organic concentrate with a 10 µm mesh for light oxidation of the organic concentrate. A drop of the final sieved palynological residue was pipetted off and mixed in one drop of polyvinyl alcohol with a glass stirring rod. Once the polyvinyl alcohol/residue had dried, one drop of clear casting resin was added to fix the coverslip.

All samples were examined with a Leitz Dialux microscope equipped with Leitz NPL fluotar objectives (10X, 25X, 40X, and 100X) and 10X WF oculars. Species identification was done at 400X, counting at 250X and 100X under white transmitted. A counting technique based on a modification of Styzen (1997) and Lorente (1986) was consistently used to obtain quantitative data for the abundance analysis of individual species. All specimens in 150 fields of view (FOV) at 250x were counted for each slide, and a subsequent screening at 100X of the entire slide (22 x40 mm) was conducted to locate and count species not overrepresented. A total of 12,763 specimens were identified and counted, with an average of 410 palynomorphs count per sample. All palynological data was transferred to Excel files and exported to Tilia (Grimm, 1991) for further analysis of results and display.

REFERENCES

Grimm E. C. (1991) TILIA and TILIA·GRAPH computer programs. Springfield. Illinois State Museum.

Lorente, M. A. (1986). *Palynology and palynofacies of the Upper Tertiary in Venezuela* [Ph.D dissertation]. Dissertationes Botanicae, Band 99. Lubrecht & Cramer Ltd., Port Jervis.

Styzen, M. (1997). Cascading counts of nannofossil abundance. *Journal of Nannoplankton Research*, *19*(1), 49. https://shorturl.at/noyMY

SUPPLEMENT 2: Palynology Sample Data Tables

The following data tables contain the raw specimen counts of sporomorphs, dinoflagellate cysts, and other palynomorphs recovered from sediment samples collected from the Arlington Archosaur Site. Data tables are organized by sample column. Complete data for all specimens can be accessed on bioRxiv at: https://doi.org/10.1101/2023.12.04.569281

Woodbine Group									**Lithostratigraphy**	**Stratigraphy**
A				B				D	**Facies Association**	
Nyssapollenites albertensis (Nichols, 1994)									**Sporomorphs' Zonation**	
Cyclonephelium membraniphorun (Dodsworth and Eldrett, 2019)									**Dinoflagellate Cyst Zonation**	
late Cenomanian									**Age**	
AASP 1-1	AASP 2-1	AASP 2-2	AASP 1-2	AASP 2-3	AASP 1-3	AASP 1-4	AASP 2-4	AASP 1-5	**Center-West Quarry AASP 1 & AASP 2 combined**	**Section**
0	0.5	8	15	41	45	18	116	134	**Thickness (cm)**	**Sample**
34	15	8	38	75	6	12	75	165	*Miscellaneous spores*	
		1		2	14	5	13	21	*Miscellaneous pollen*	
1	3	15		3	26	12		4	*Bisaccate pollen (conifers)*	
2	24		1	4	2	13	9		*Triplanosporites sinosus*	
6	2	3	1		4	4	1	3	*Appendicisporites erdtmannii*	
22	3	2		7	2	6	12	3	*Appendicisporites matesovae*	
8				6				4	*Aquilapollenites sp.*	
2	5	1	3		3	8	3	5	*Classopollis spp.*	
3	1		2		1	1			*Cicatricosisporites spp.*	
3			12						*Psilatriletes sp.*	
2	1								*Osmundacidites sp.*	
4				5					*Anemia poolensis*	
1				3			5		*Appendicisporites trichacanthus*	
1							5		*Appendicisporites unicus*	
2									*Aquilapollenites turbidus*	
	45	28	1	12	2		1	2	*Cicatricosisporites venustus*	
	55	25	1	12	1	2	3	8	*Cyathidites australis*	
	5	1	1	6	28			8	*Cyathidites minor*	
	6	35		36	2	8	39	8	*Cyathidites sp.*	

	8			8			6		*Aquilapollenites psilatus*	Sporomorphs
	25							12	*Cicatricosisporites brevilaesuratus*	
	1		2	1					*Classopollis obidosensis*	
	5	3	2	1			3		*Gleicheniidites senonicus*	
	3								*Cupuliferoidaepollenites cf. microscabratus*	
	1			1			1		*Pityosporites sp.*	
	1								*Psilamonocolpites sp.*	
	1			1					*Rugubivesiculites woodbinensis*	
	2			1		1			*Tricolpites hians*	
	1	1		1	1			1	*Tricolpites sp.*	
		2		1					*Monosulcites sp.*	
		1							*Acacia sp.*	
		1			4	2		2	*Lycopodiumsporites crassimacerius*	
			2	25	12	16			*Cicatricosisporites hallei*	
			3		21	5	6		*Abietineaepollenites sp.*	
			1		1				*Laevigatosporites sp. (Blechnum type)*	
			1			1		2	*Classopollis classoides*	
			14	2			6		*Deltoidospora spp.*	
			1						*Elaterosporites sp.*	
			1					2	*Ephedripites sp.*	
			1						*Matonisporites cf. equiexinus*	
			6						*Inaperturopollenites sp.*	
			1						*Polypodiaceoisporites sp.*	
			1				4		*Zlivisporis cenomanianus*	
				1					*Afropollis sp. (frag.)*	
				1					*Bacutricolpites constrictus*	
					1	1			*Calamospora cf. mesozoica*	
				5	1				*Callialasporites cf. dampieri*	
				2					*Callialasporites segmentatus*	
				1	11	3	1		*Callialasporites sp.*	
				1	2				*Camarozonosporites rudis*	
				1	1	1			*Camarozonosporites spp.*	
				3	1				*Pilosisporites ericius*	
				1				1	*Dichastopollenites dunveganensis*	
				1					*Ischyosporites crateris*	

				1			1		*Camarozonosporites wrennii*
				1					*Inaperturotetradites scabratus*
				1					*Ginkgocycadophytus? sp.*
				1		2			*Psilamonocolpites? sp. (finely perforate)*
				2					*Rugubivesiculites rugosus*
				4					*Trilobosporites sp.*
				1					*Pseudowalchia sp.*
					1				*Abietineaepollenites microreticulatus*
					1				*Classopollis cf. maljawkineae*
					1				*Latipollis sp.*
					5				*Perfotricolpites sp.*
					1				*Podocarpidites cf. biformis*
					1		12		*Podocarpidites sp.*
						8			*Laevigatosporites sp.*
						1			*Classopollis cf. senegalensis*
						1	12		*Deltoidospora hallii*
					1	1			*Stellatopollis largissimus*
						1			*Taurocusporites sp.*
							1		*Perinopollenites elatoides*
							1		*Lycopodiumsporites sp.*
							2		*Foraminisporis cf. paucispinosus*
							1		*Foraminisporis sp.*
							1		*Ghoshispora sp.*
							1		*Cicatricosisporites crassiterminatus*
							1		*Verrutriletes verus*
14	22	15	22	39	30	24	28	17	**Species diversity**
91	213	127	96	241	158	115	226	251	**Specimens abundance**

AASP 1-2 Palynology Chart

Palynologist M A Lorente ARLINGTON ARCHOSAUR SITE Sampled by Ch. Noto

Stratigraphy

Lithostratigraphy	Woodbine Group
Facies Association	A (AASP 1-1 – AASP 1-2); B (AASP 2-3 – AASP 2-4); D (AASP 1-5)
Sporomorphs' Zonation	*Nyssapollenites albertensis*
Dinoflagellate Cyst Zonation	*Cyclonephelium membraniphorun*
Age	late Cenomanian

Group	AASP 1 & AASP 2 Dinoflagellates Combin (Section Sample)	AASP 1-1	AASP 2-1	AASP 2-2	AASP 1-2	AASP 2-3	AASP 1-3	AASP 1-4	AASP 2-4	AASP 1-5
	Thickness (cm)	0	0.5	8	15	41	45	18	116	134
Dinoflagellate Cysts	*Miscellaneous dinoflagellates*		1	2		7	15	32	5	16
Dinoflagellate Cysts	*Apteodinium? Sp.*					1				
Dinoflagellate Cysts	*Ascodinium cf. acrophorum*						1			
Dinoflagellate Cysts	*Cyclonephelium compactum - Cyclonephelium membraniphorum*		22	5						
Dinoflagellate Cysts	*Scriniodinium campanula*								1	
Dinoflagellate Cysts	*Eurydinium glomeratum*			1						
Dinoflagellate Cysts	*Florentinia sp.*				3			1		
Dinoflagellate Cysts	*Florentinia khaldunii*	4	1	2		1			5	
Dinoflagellate Cysts	*Isabelidinium? globosum*			7	1					
Dinoflagellate Cysts	*Litosphaeridium sp.*		2							
Dinoflagellate Cysts	*Odontochitina sp.*				1					
Dinoflagellate Cysts	*Oligosphaeridium complex*			1						
Dinoflagellate Cysts	*Oligosphaeridium pulcherrimum*	1	2	1		7	3		1	
Dinoflagellate Cysts	*Ovoidinium cf. implanum*			11		2			1	
Dinoflagellate Cysts	*Ovoidinium? sp.*			1						
Dinoflagellate Cysts	*Palaeotetradinium silicorum*					1				
Dinoflagellate Cysts	*Phelodinium cf. kozlowskii*			2						
Dinoflagellate Cysts	*Prolixosphaeridium cf. parvispinum*			1					1	
Dinoflagellate Cysts	*Spiniferites sp.*			1						
Dinoflagellate Cysts	**Diversity (Total species)**	2	5	12	3	6	3	2	6	1
Dinoflagellate Cysts	**Abundance (Total specimens)**	5	28	35	5	19	19	33	14	16
Acritarchs	*Leiosphaeridia sp.*		35							
Acritarchs	*Filisphaeridium fimbriatum*					6	1	1	1	
Acritarchs	*Fromea sp.*			1						
Acritarchs	**Diversity (Total species)**		1	1		1	1	1	1	
Acritarchs	**Abundance (Total specimens)**		35	1		6	1	1	1	

p.1

AASP 1-2 Palynology Chart Supplemental Material

Palynologist M A Lorente ARLINGTON ARCHOSAUR SITE Sampled by Ch. Noto

p.2

Stratigraphy					Section	Sample	Fresh water algae									Fungi		
Lithostratigraphy	**Facies Association**	**Sporomorphs' Zonation**	**Dinoflagellate Cyst Zonation**	**Age**	**AASP 1 & AASP 2 Other palynomorphs Combined**	**Sample cm from base**	*Schizophacus laevigatus*	*Schizophacus majusculus*	*Schizosporis reticulatus*	*Zygnemataceae spp.*	*Algae filaments*	*Botryococcus spp.*	*Pediastrum spp.*	**Species diversity**	**Specimens abundance**	*Pluricellaesporites psilatus*	*Fungal remains -hyphae-*	*Fungal fruit bodies*
Woodbine Group	D	*Nyssapollenites albertensis*	*Cyclonephelium membraniphorun*	late Cenomanian	AASP 1-5	134	2						1	2	3	5		
	B				AASP 2-4	116					2			1	2			
					AASP 1-4	18	28			4			1	3	33	8		
					AASP 1-3	45	5							1	5			
					AASP 2-3	41		1				1		2	2			
	A				AASP 1-2	15	3		1			1		3	5	2		
					AASP 2-2	8								0	0		1	
					AASP 2-1	0.5		25	1					2	26		25	1
					AASP 1-1		16							1	16	4		

AASP 3-4 Palynology Chart Supplemental Material

Palynologist M. A. Lorente ARLINGTON ARCHOSAUR SITE Sampled by Ch. Noto p1

Lithostratigraphy	Facies Association	Sporomorphs' Zonation	Dinoflagellate Cyst Zonation	Age	Section: Center Quarry_Combined 3 & 4	Sample: Depth (cm)	*Miscellaneous spores*	*Miscellaneous pollen*	*Biretisporites potoniaei*	*Distaltriangulisporites sp.*	*Cyathidites spp.*	*Appendicisporites matesovae*	*Aquilapollenites psilatus*	*Bisaccate pollen (conifers)*	*Cicatricosisporites venustus*	*Cyathidites australis*	*Verrutriletes verus*	*Deltoidospora hallii*	*Podocarpidites sp.*	*Inaperturopollenites hiatus*	*Cycadopites sp.*	*Concavissimisporites sp.*	*Cyathidites minor*	*Foraminisporis* sp.	*Ischyosporites crateris*	*Proxapertites spp.*	*Rugubivesiculites rugosus*	*Appendicisporites spp.*	*Zlivisporis cenomanianus*	*Pseudowalchia spp.*	*Appendicisporites erdtmannii*	*Aquilapollenites cf. psilatus*	*Abietineaepollenites sp.*	*Cicatricosisporites spp. (dorogensis?)*	*Contignisporites sp.*
Woodbine Group	D	*Nyssapollenites albertensis* (Nichols, 1994)	*Cyclonephelium membraniphorun* (Dodsworth and Eldrett, 2019)	late Cenomanian	AAS 4-6	150	220	10			100		4	34		60					1			1			6		1					2	
					AAS 3-12	138	76	13			75	3	15	36	3	30		2					6		1		14		2		6	18	6	9	
					AAS 4-5	131	120	4			50		4	18	1	60					5	1					14						4	3	
	B				AAS 3-11	127	36	21			39	6	1	28	1	21	3	2							2		7				12	12		20	
					AAS 3-10	115	182	26			120	4	24	60	5	5	1	1					18		1		46		3		5	12	18	3	
					AAS 4-4	110	43	10			28	2	2	9		16					4												3		
					AAS 3-9	100	110	20			30		6	36	1	16				2					1		12					6	8	3	
					AAS 3-8	85	123	13			125	8	8	16	15	12				2			6		3			1			3	16		7	
					AAS 3-7	75	126	14			40	9	16	14	4	4		6		4					3						5	2	5	2	
					AAS 4-3	55	215	79			360		12	16	12	8						2		1	1		26	2			10	14	8	2	
					AAS 3-6	51	110	0			100	8	6	14	18	30		2		10						1					22	18	12	1	
					AAS 3-5	43	100	16			96	3	32	4	18	8		4	20	8			4								17	17	12		
					AAS 3-4	38	120	7			50	3	2	4	3	12		1	4				3		1						3	19	6		
	A				AAS 3-3	31	83	4				13	5	4	9	16		1	23	1	50		13								10	18	9		
					AAS 4-2	15	108	0			36	8	8	20	3	28				12	1				4		4			16	8	10	4	20	
					AAS 3-2	19	108	5			100	14	35	6	20	1		9	8	20	7	1									10	80		1	1
					AAS 3-1	3	30	10	4	1	6	2	2	2	6	2		1	4												8	6	8	22	
					AAS 4-1	0	78	24			20	10	6	4	4	10	2				5	2	4	8	2	4	1	6	1	10					

		3		1	1	12	2	2	2	2	2	2	11		2			*Gleicheiidites senonicus*
		1		2	1			2	2	6	2		1		2	5	4	*Dichastopollenites dunveganensis*
		1		1									1		8			*"Perfomonocolpites" sp.*
		1	3			12		16		1				7		6		*Cicatricosisporites crassiterminatus*
		1						2										*Impardecispora purverulenta*
		1																*Liliacidites cf. inaequalis*
		10																*Callialasporites segmentatus*
		20			2	12												*Deltoidospora sp.*
			1							30								*Tricolpites spp.*
				1		15	28	23	10	6				2		2		*Pilosisporites ericius*
				2		2												*Laevigatosporites sp.*
				2	1	12	4		2									*Cicatricosisporites hallei*
				8	1		1							1		1		*Callialasporites sp.*
				1		1												*Echitriletes sp.*
				4		6	10		9	2								*Podocarpidites biformis*
				3	2	4	6	3	2	4	7	3	4	3			2	*Stellatopollis largissimus*
				1														*Cicatricosisporites hughesii*
				1			6										1	*Pristinuspollenites microsaccus*
				6	10	4				3								*Inaperturopollenites sp.*
				2		1	4		1									*Camarozonosporites wrennii*
				2		2						5	1	1	5		4	*Classopollis spp.*
					2	12												*Anemia poolensis*
					5													*Abietineaepollenites microreticulatus*
						1	4	12										*Appendicisporites cf matesovae*
						1												*Exesipollenites sp.*
						1												*Matonisporites excavatus*
						1												*Artiopollis indivisus*
						1												*Classopollis torosus*
						1					1		3	8				*? Perinopollenites elatoides*
						2		1	1							3		*Ephedripites sp.*
									1									*? Lycopodiacidites tortus*
										2							4	*Ariadnaesporites sp.*
								4		1								*Camarozonosporites sp.*
										1								*Araucariacites sp.*
										1			1			1		*Reticulatisporites cf. arcuatus*
										1								*Lycopodiumsporites cf. dentimuratus*
										6								*Parvisaccites cf. rugulatus*
										18								*Rousea cf. georgensis (small < 20 microns)*
								2		4	14		60					*Aesculiidites dubius*
								6					3		4			*Monosulcites inspissiatus*
													1	2				*Retitricolpites cf. geranioides*
								1					1	2				*Cicatricosisporites subrotundus*
													1			1		*Apiculatisporis cf. asymmetricus*
								2				5	5	2	16	8	20	*Cupuliferoidaepollenites cf. microscabratus*
								1									2	*Tricolpites hians*
								1										*Camarozonosporites rudis*

Sporomorphs

p.2

								1										*Triporoletes cenomanianus*	
								7										*Classopollis classoides*	
											2		2	1				*Ghoshispora? sp.*	
											1		18	1				*Retitricolpites maximus*	
												8			8		4	*Azolla spore cluster*	
												1						*Azolla sp.*	
												1					4	*Inaperturotetradites cf. scabratus*	
												3			40		6	*Matonisporites equiexinus*	
																	16	*Tucanopollis sp.*	
19	**16**	**25**	**19**	**30**	**24**	**35**	**24**	**33**	**24**	**31**	**20**	**17**	**33**	**26**	**20**	**25**	**22**	**Diversity sporomorphs**	
201	**114**	**464**	**294**	**296**	**263**	**462**	**417**	**854**	**284**	**446**	**280**	**145**	**647**	**241**	**369**	**342**	**506**	**Abundance Sporomorphs**	p.3

AASP 3-4 Palynology Chart Supplemental Material

Palynologist M. A. Lorente ARLINGTON ARCHOSAUR SITE Sampled by Ch. Noto p.1

Dinoflagellate Cysts

Section: Center Quarry_Combined 3 & 4	AAS 4-1	AAS 3-1	AAS 3-2	AAS 4-2	AAS 3-3	AAS 3-4	AAS 3-5	AAS 3-6	AAS 4-3	AAS 3-7	AAS 3-8	AAS 3-9	AAS 4-4	AAS 3-10	AAS 3-11	AAS 4-5	AAS 3-12	AAS 4-6
Depth (cm)	0	3	19	15	31	38	43	51	55	75	85	100	110	115	127	131	138	150
Facies Association	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	D	D	D
Miscellaneous dinoflagellates	6	4	12	8	8	12	20	25	7	15	4	75	3	10	22		12	2
Florentinia cf. khaldunii	7	4	8	8	12	10	16	20	3	3	1	1		4	6			
Oligosphaeridium pulcherrimum	20		2		2	2	12	20	7	4	4		1		2			
Cyclonephelium compactum-Cyclonephelium membraniphorum	5		2	1	2	6		2							4		1	
Ascodinium cf. *acrophorum*	10																	
Prolixosphaeridium parvispinum / Kiokansium williamsii	1			10					4						1		1	
Cyclonephelium sp.	1							2	1		1				2			
Oligosphaeridium complex	3										1			1	2			
Oligosphaeridium poculum	2														3			
Wallodinium luna			1															
Odontochitina sp.			1															
Pseudoceratium sp.													1					
Isabelidinium? cf. globosa					5											1		
Circulodinium sp.								4										
Ovoidinium implanum									1									
Epelidosphaeridia spinosa									18		10	5		1	3			
Palaeoperidinium sp.									1		2				12			
Chichaouadinium cf. vestitum											4							
Subtilisphaera deformans											2			3	2			
Kiokansium unituberculatum												20		10	12			
Florentinia? torulosa															18			
Dinoflagellates Diversity	9	2	6	4	5	4	3	6	8	3	9	4	3	6	13	1	3	1
Dinoflagellates Abundance	55	8	26	27	29	30	48	73	42	22	29	101	5	29	89	1	14	2

Acritarchs

Center Quarry_Combined 3 & 4	AAS 4-1	AAS 3-1	AAS 3-2	AAS 4-2	AAS 3-3	AAS 3-4	AAS 3-5	AAS 3-6	AAS 4-3	AAS 3-7	AAS 3-8	AAS 3-9	AAS 4-4	AAS 3-10	AAS 3-11	AAS 4-5	AAS 3-12	AAS 4-6
Depth (cm)	0	3	19	15	31	38	43	51	55	75	85	100	110	115	127	131	138	150
Facies Association	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	D	D	D
Fromea amphora				1														6
Leiosphaeridia sp.	8			24					9				14			18		3
Acanthomorph acritarchs	2			2									2			1		1
Filisphaeridium cf. fimbriatum											2	30						4
Acritarch Diversity	2	0	0	3	0	0	0	0	1	0	1	1	2	0	0	2	0	4
Acritarch Abundance	10	0	0	27	0	0	0	0	9	0	2	30	16	0	0	19	0	14

p.2

Section: Other Palynomorphs

Center Quarry_Combined 3 & 4	AAS 4-1	AAS 3-1	AAS 3-2	AAS 4-2	AAS 3-3	AAS 3-4	AAS 3-5	AAS 3-6	AAS 4-3	AAS 3-7	AAS 3-8	AAS 3-9	AAS 4-4	AAS 3-10	AAS 3-11	AAS 4-5	AAS 3-12	AAS 4-6
Depth (cm)	0	3	19	15	31	38	43	51	55	75	85	100	110	115	127	131	138	155
Facies Association	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B	D	D	D
Fungal remains -hyphae-	10	1		14			12											
Fungal fruit bodies																		
Algae filaments		1		1									5	4		6	3	
Algae remains (drop like)		1									5	10		13	9			
Schizophacus laevigatus/ Ovoidites parvus	12				3					3	45	54	4	2	12	28	9	1
Schizophacus majusculus	4		2		2		10		3	18	40	30	3	4	9	8	30	5
Schizosporis reticulatus (large)		1			1	1					2		1		2	1		
Schizosporis reticulatus					1	1												
Botryococcus spp.													19		12	2	3	1
Pediastrum spp.													74	7	18	4		10
Terrestrial/Fresh water Diversity	**3**	**4**	**1**	**2**	**4**	**2**	**2**	**0**	**1**	**2**	**4**	**3**	**6**	**5**	**6**	**6**	**4**	**4**
Terrestrial/Fresh water Abundance	**26**	**4**	**2**	**15**	**7**	**2**	**22**	**0**	**3**	**21**	**92**	**94**	**106**	**30**	**62**	**49**	**45**	**17**

AASP 5 Palynology Chart

Supplemental Material

Palynologis Maria Antonieta Lorente

ARLINGTON ARCHOSAUR SITE

Sampled by Christopher Noto

Stratigraphy	Lithostratigraphy	Woodbine Group
	Facies Association	A
	Sporomorphs' Zonation	*Nyssapollenites albertensis* (Nichols, 1994)
	Dinoflagellate Cyst Zonation	*Cyclonephelium membraniphorun* (Dodsworth and Eldrett, 2019)
	Age	late Cenomanian
Section	Center Quarry	AASP 5-1
Sample	Estimated Depth (cm)	20
Facies	Lithofacies	A
Sporomorphs	*Miscellaneous spores*	107
	Miscellaneous pollen	18
	Cyathidites spp.	60
	Appendicisporites matesovae	4
	Bisaccate pollen (conifers)	45
	Cicatricosisporites venustus	9
	Cyathidites australis - Cyathidites major	54
	Appendicisporites erdtmannii / Plicatella fu	6
	Triplanosporites sinuosis	24
	Abietineaepollenites sp.	4
	Rugubivesiculites cf. rugosus	7
	Taxodiaceaepollenites sp.	36
	Concavisporites rugulatus - Gleicheiidites s	3
	Dichastopollenites dunveganensis	1
	Stellatopollis largissimus	3
	Tricolpites hians	1
	Classopollis sp.	1
	Sabalpollenites scabrus / Eucommiidites sp	6
	Perfomonocolpes sp.	1
	Pristinuspollenites microsaccus	1
	Diversity	20
	Sporomorphs Abundance	391
Section	Center Quarry	AASI
Sample	Estimated Depth (cm)	20
Facies	Lithofacies	A
Algae	*Schizophacus cf. majusculus*	2
	Pediastrum sp.	3
	Zygnemataceae	3
	Diversity	3
	Abundance	8

AASP 5 **Palynology Chart** **Supplemental Material**

Palynologist M. A. Lorente **ARLINGTON ARCHOSAUR SI' Sampled by Ch. Noto**

Stratigraphy					Section	Sample	Dinoflagellate Cysts									Acritarchs			
Lithostratigraphy	**Facies Association**	**Sporomorphs' Zonation**	**Dinoflagellate Cyst Zonation**	**Age**	**Center Quarry**	**Estimated Depth (cm)**	**Lithofacies**	*Miscellaneous dinoflagellates*	*Oligosphaeridium pulcherrimum*	*Cyclonephelium compactum-Cyclonephelium membraniphorum*	*Prolixosphaeridium parvispinum*	*Ovoidinium implanum*	*Epelidosphaeridia cf. spinosa*	***Diversity***	***Abundance***	*Leiosphaeridia sp.*	*Acanthomorph acritarchs*	***Diversity***	***Abundance***
Woodbine Group	**A**	***Nyssapollenites albertensis*** **(Nichols, 1994)**	***Cyclonephelium membraniphorun*** **(Dodsworth and Eldrett, 2019)**	**late Cenomanian**	AASP 5-1	20	A	16	15	12	1	4	40	6	88	46	1	2	47

AASP 6 - 7 Palynology Chart — **Supplemental Material**

Palynologist: M A Lorente — ARLINGTON ARCHOSAUR SITE — Sampled by Christopher Noto

Stratigraphy	Woodbine Group			**Lithostratigraphy**
		A	B	**Facies Association**
	Nyssapollenites albertensis **(Nichols, 1994)**			**Sporomorphs' Zonation**
	Cyclonephelium membraniphorun **(Dodsworth and Eldrett, 2019)**			**Dinoflagellate Cyst Zonation**
	late Cenomanian			**Age**
Section	AASP 7-1	AASP 6-1	AASP 7-2	**Center Quarry**
Sample	10	15	40	**Estimated Depth (cm)**
Sporomorphs	112	140	226	*Miscellaneous spores*
	14	34	16	*Miscellaneous pollen*
	76	44	152	*Cyathidites spp.*
	6	8	16	*Appendicisporites matesovae*
	6	20	20	*Aquilapollenites psilatus*
	32	42	66	*Bisaccate pollen (conifers)*
	44	24	20	*Cicatricosisporites venustus*
	30	46	62	*Cyathidites australis*
	8	10	11	*Cycadopites sp. / Ginkgocycadophytus s*
	20	4	22	*Appendicisporites erdtmannii*
	20	14	24	*Triplanosporites sinuosis*
	16	10	8	*Cicatricosisporites spp. (dorogensis?)*
	10	12	8	*Rugubivesiculites cf. rugosus*
	24	8	12	*Taxodiaceaepollenites sp.*
	8	6	10	*Gleicheiidites senonicus*
	10	2	16	*"Perfomonocolpites" sp.*
		1	2	*Dichastopollenites dunveganensis*
		6	12	*Stellatopollis largissimus*
		1	16	*Triplanosporites sp.*
		1		*Ephedripites sp.*
		1		*Camarozonosporites sp.*
		1		*Tricolpites hians*
	4		6	*Ischyosporites crateris*
	6		2	*Abietineaepollenites sp.*
	1			*Classopollis sp.*
	2			*Perfotricolpites spp.*
			6	*Pristinuspollenites microsaccus*
			1	*Zlivisporis cenomanianus / Hymenozono*
			16	*Rugubivesiculites rugosus*
			1	*Camarozonosporites rudis*
	20	22	25	**Sporomorph Diversity**
	449	435	751	**Sporomorphs Abundance**

AASP 6 - 7 **Palynology Chart (2)** **Supplemental Material**

Palynologis Maria Antonieta Lorente ARLINGTON ARCHOSAUR SITE Sampled by Christopher Noto

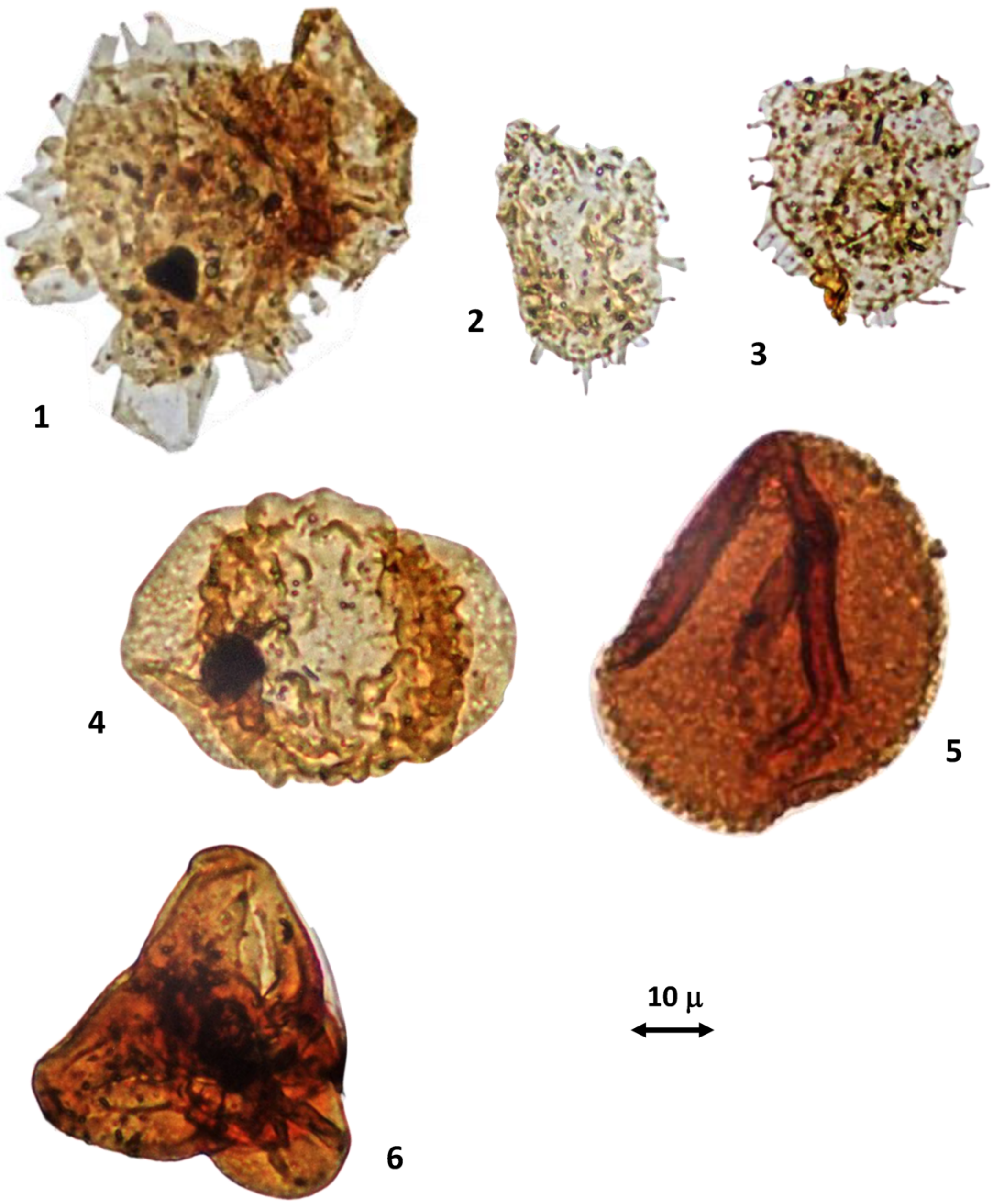
Stratigraphy				
Lithostratigraphy	**Facies Association**	**Sporomorphs' Zonation**	**Dinoflagellate Cyst Zonation**	**Age**
Woodbine Group	B (AASP 7-2); A (AASP 6-1, AASP 7-1)	*Nyssapollenites albertensis* (Nichols, 1994)	*Cyclonephelium membraniphorun* (Dodsworth and Eldrett, 2019)	late Cenomanian

Section	Sample	Dinoflagellate Cysts								Acritarch		
Center Quarry	**Estimated Depth (cm)**	*Miscellaneous Dinoflagellates*	*Florentinia cf. khaldunii*	*Oligosphaeridium pulcherrimum*	*Cauveridinium membraniphorum* (Ccm ple	*Kiokansium williamsii*	*Epelidosphaeridia cf. spinosa*	DIVERSITY	ABUNDANCE	*Leiosphaeridia sp.*	DIVERSITY	ABUNDANCE
AASP 7-2	40	10	12	2	4	2	24	6	54	34	1	34
AASP 6-1	15				4		28	2	32	26	1	26
AASP 7-1	10	10	8		1		16	4	35	40	1	40

Section	Sample	OTHER PALYNOMORPHS (Terrestrial)								
Center Quarry	**Estimated Depth (cm)**	*Fungal remains -hyphae-*	*Algae filaments / remains*	*Schizophacus laevigatus/ Ovoidites parvus*	*Schizophacus cf. majusculus*	*Schizosporis reticulatus (megaspore)*	*Pediastrum*	*Zygnemataceae*	DIVERSITY	ABUNDANCE
AASP 7-2	40		4		5	1		2	4	12
AASP 6-1	15	4		6					2	10
AASP 7-1	10	4				1	1	4	4	10

SUPPLEMENT 3: Palynology Specimen Plate

PLATE



1. *Cyclonephelium compactum* (Deflandre and Cookson, 1955) Fensome et al., 2019 – *C. membraniphorum* Cookson and Eisenack, 1962. Ccm morphological plexus, ventral view. Sample AASP 5-1. Focus stacked image*.
2. *Kiokansium williamsii* Singh, 1983. Sample AASP 3-11. Focus stacked image*.
3. *Kiokansium unituberculatum (*Cookson and Eisenack, 1962) Duxbury, 1983. Sample AASP 3-10. Focus stacked image*.
4. *Rugubivesiculites rugosus* Pierce, 1961. Sample AASP 3-10. Focus stacked image*.
5. *Pilosisporites ericius* Delcourt, 1955. Sample AASP 4-3. Focus stacked image*.
6. *Cupuliferoidaepollenites microscabratus* Kovalch and Ditcher, 1985. AASP AAS 3-10 (tetrad). Focus stacked image*.

*The image has been digitally processed, combining multiple images at different focal distances (stacking).

Supplement 4: Palynology Interpretation

1. Palynomorphs as sedimentary particles at the AAS

The palynomorph assemblage of any sedimentary succession commonly has three main components: in situ palynomorphs, redeposited contemporaneous palynomorphs, and reworked palynomorphs from older sediments. Paleoenvironmental interpretation based on palynological results is made by examining the different palynomorph group tendencies in abundance and diversity throughout the section rather than relying on isolated samples.

Assuming normal depositional conditions and no significant reworking of older sediments, to determine which components of the assemblage are in situ, hence represent a "true" environmental signal, and which elements are transported representing the signal from the greater drainage basin, the AAS section must be analyzed from a "source to sink" point of view (Figure 8 in paper's main text). The source and transfer areas are all areas topographically above base level, where there is a balance between deposition and erosion (Catuneanu, 2006). The base-level surface is typically either the water table (continental-terrestrial) or the ocean surface (marine).

Palynomorphs behave like sediment particles when transported by water and wind, with the caveat that organic matter has a lower density (OM: 1.1-1.25-1.4 g/cm3, Muller 1959) than minerals (Qz: 2.65 g/cm3, Mindata, n. d.) The fluvial systems and wind currents typically transport the palynological elements produced upstream (source and transfer zones) into the sink area. Pollen produced in the basinal (sink) areas, e.g., lakes, inter-distributary bays, lagoons, and seas, are considered in situ. Moving from down-dip depositional paleoenvironments into more up-dip positions may imply either removal and redeposition by "high" energy events, e.g., storms, storm surges, flooding of lowland areas by tsunami, or true or apparent marine transgression.

A model for interpreting the palynological associations found in different depositional paleoenvironments of the AAS site is shown in Figure 7 (main text). The diagram illustrates how palynomorphs were dispersed across the topographic profile, from source to sink, i.e., hinterland to the shallow marine shelf or open marine basin. The model in Figure 7 (main text) shows the images of palynomorphs found at the AAS site.

Purely terrestrial paleoenvironments include upland areas (mountains and hills, hinterland), river channels, floodplains (including levees, crevasse splays, oxbow lakes, ponds, and small lakes), and the lower gradient areas along coastal plain or delta plain lowlands. Transitional systems are generally found within the low-gradient coastal plain, including flood basins, the lower delta plain, coastal marshes, beaches, dunes, tidal, lagoons, bays and interdistributary bays. These paleoenvironments all may record marine influence. Tides and waves can play a considerable role during deposition in bays, tidal marshes, barrier islands, tidal channels, tidal inlets, etc.

In terrestrial environments, the assemblage is assumed to contain in situ sporomorphs and other freshwater palynomorphs. Deposits would also likely contain some grains transported by wind and water from uplands. Groot (1966) suggests that the regional vegetation of the area drained by a river system has a greater impact on the pollen spectra than the local plant communities. Very few samples in the AAS sections represent exclusively terrestrial paleoenvironments since most assemblages bear marine palynomorphs.

In tidal flats and other coastal tidally influenced environments such as brackish water marshes, lagoons, estuaries, river mouths, deltas, the lower delta plain, etc., the assemblage would be dominated by transported "contemporaneous" terrestrial sporomorphs from uplands, and in lower proportions a local "at the foot of the tree" assemblage represented by a few species with highly abundant specimens. Hardy and Wrenn (2009), in a study on palynomorph associations in the modern tropical Mahakam delta, found that tidally-influenced sub-environments maintain consistent levels of pollen, embryophyte spores, and fungal spores. The AAS site (Figures 1 to 4, main text) includes some levels that might be tidally influenced, such as Facies Association (FA) A, the lower part of Facies Association (FA) B and Facies Association (FA) D, based on the presence of *Classopollis* sp. (extinct Cheirolepidiaceae family, inhabitant of arid coastal salt marshes) and/or Taxodiaceae pollen and the presence of a few euryhaline dinoflagellate cyst types. From an abundance-of-specimens point of view, these assemblages are dominated by terrestrial palynomorphs.

Signals observed in the palynomorph assemblage are from at least three parts of the source and transit areas of the source-to-sink system. They are evident in the assemblage as follows:

- Pollen in Facies Association (FA) A and B indicate sedimentation in transitional terrestrial to marine environments, with vegetation signals from the alluvial and coastal plain, with wetlands and swamp forest vegetation, with indications of brackish to tidal influence, especially in the upper part of Facies Association (FA) A and the middle and lower part of Facies Association (FA) B. The presence of a moderately rich dinoflagellate cysts assemblage indicate that the sink area was most probably proximal shallow marine.

- Pollen in Facies Association (FA) D is consistent with deposition in tidally influenced areas based on the presence of *Classopollis* spp. (Cheirolepidiaceae family). In Facies Association (FA) D, the presence of pollen from Cycadophyta, a plant associated with beetle pollination with very limited pollen dispersion, may indicate sedimentation in or near widespread tropical lowland swamp areas.

In nearshore paleoenvironments, the assemblage may have a transported, variable, abundant terrestrial sporomorph assemblage mixed with dinoflagellate cyst species that indicate salinity variations, including reduced salinities. Hardy and Wrenn (2009) found that in marine nearshore and shelf environments, the amount of marine palynomorphs (zooplankton and phytoplankton) increases gradually towards offshore, while conversely, the percentage of sporomorphs decreases. On the other hand, relatively big ornate spores may be present, as well as saccate pollen grains transported from the uplands. The abundance of megaspores is an indicator of proximity to active terrestrial sources, being abundant in fluvial, marsh, lagoonal, and proximal marine environments, with abundance decreasing with the distance to the parent plant (e.g., Winslow, 1962; Speelman & Hills, 1980; Streel & Bless,1980). The AAS sections show the presence of spores from floating freshwater ferns and angiosperm pollen in assemblages dominated by pteridophytes and conifers mixed with a dinoflagellate cyst assemblage moderately rich in species. The dinoflagellate cysts are the only elements considered in situ, representing paleoenvironments in the sink area, while the rest of the assemblage represents the signal from upland vegetation. These assemblages are common in Facies Association (FA) A and the lower part of Facies Association (FA) B.

In the outer neritic and open marine environments, the number of dinoflagellate cysts and other phytoplankton should increase in diversity and abundance and include smaller size transported sporomorphs and saccate pollen related to sorting during transport. Stanley (1965) suggests a noticeable increase in pollen and spores as one moves from a few to over 100 kilometers away from the shoreline into open water. Williams and Sarjeant (1967) note that dinoflagellate cysts rely on specific marine conditions such as temperature, turbidity, and light, as well as the circulation of marine currents. Furthermore, marine currents mix dinoflagellate cysts and acritarchs that are "in situ" with continental-derived biotic assemblages. In the AAS section, a few rich dinoflagellate cyst assemblages are mixed with bisaccate spores and smaller angiosperm grains, suggesting the presence of shallow marine paleoenvironments in some parts of the section, such as in the upper part of Facies Association (FA) B.

Towards the distal deltaic, shelf, and offshore environments, the assemblages should be dominated by dinoflagellate cysts, saccate pollen, and very small sporomorphs transported by different marine currents. Assemblages suggestive of this outer neritic and open marine environment were not observed in the AAS section.

2. Paleoecological implications of dinoflagellate cysts

According to Harris and Tocher (2003), in the assemblages from the Western Interior Sea, it is possible, using cluster analysis, to differentiate three paleoecological groups of dinoflagellate cysts based on their tolerance of salinity variations:

- Euryhaline, tolerating or perhaps preferring lowered salinities. Some species in this group are, among others, *Cyclonephelium brevispinatum* (now *Tenua hystrix*)*, Cyclonephelium*(now *Aptea*?) *vannophorum,* and *Oligosphaeridium pulcherrimum*.
- Stenohaline, preferring normal marine salinities. Species that cluster together per Harris and Tocher (2003) are, among others, *Oligosphaeridium totum* and *Spiniferites ramosus reticulatus*.
- Offshore, only tolerant of stenohaline conditions. Species in these clusters include *Cyclonephelium membraniphorum*, among others.
- Most of the species found in the AAS support euryhaline conditions, with tolerance to lowered salinity conditions (Table 1).

Paleoecology Salinity	**Euryhaline**	**Stenohaline**	**Offshore**
Restricted	*Kiokasium williamsii* (Gonyaulacaceae).		
Abundant, but not restricted	*Florentinia* spp. (Gonyaulacaceae—Cribroperidinioideae).		*Cyclonephelium membraniphorum* (Gonyaulacaceae–Areoligeraceae).
	Cyclonephelium (now *Aptea*?) *vannophorum* (Gonyaulacaceae–Areoligeraceae).		
	Oligosphaeridium pulcherrimum (Gonyaulacaceae—Leptodinioideae).		
	Oligosphaeridium spp. (Gonyaulacaceae—Leptodinioideae).		

Table 1. Paleoecological implications of dinoflagellate cysts. Salinity tolerance of dinoflagellate cysts found at the Arlington Archosaur Site, based on Harris and Tocher (2003).

3. Refinement of Woodbine Gr Age based on dinoflagellate cysts

At the AAS, there is an apparent top occurrence of Cyclonephelium compactum – membraniphorum (Ccm Plexus). The Ccm Plexus has a continuous presence through the AAS section with a major abundance pick >11% (Figure 1) at the base of FA-A, with several smaller picks (≥ 6%) at the base and top of FA-B. We interpret this to indicate the onset of a Boreal water incursion consistent with the PCE.

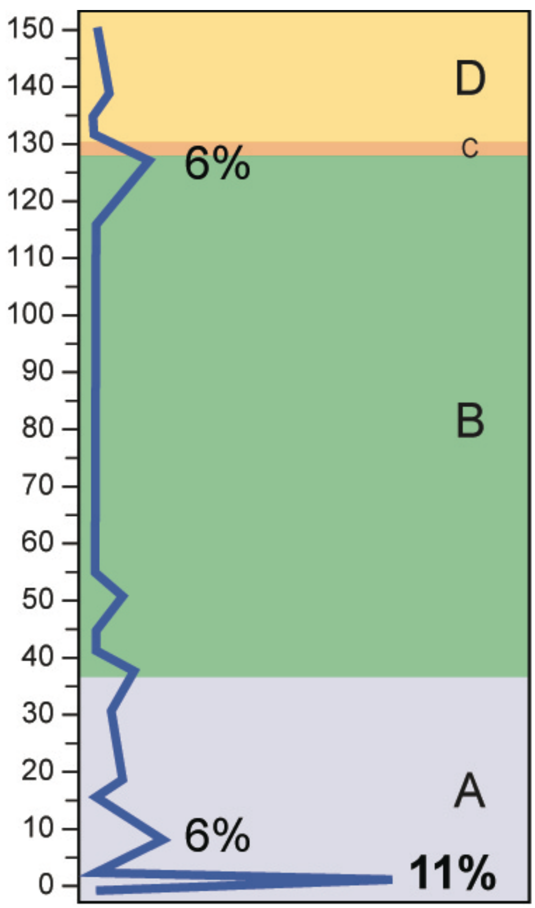


Figure 1 Abundance of the Ccm plexus along the AAS section, with raw counts (line) and percent of sample (numbers at peaks). Facies associations follow those described in Figures 3 and 4 of main text. Note no samples were collected from FA-C.

References

Abbink, O., Van Konijnenburg-Van Cittert, J., & Visscher, H. (2004). A sporomorph ecogroup model for the Northwest European Jurassic - Lower Cretaceous: Concepts and framework. *Netherlands Journal of Geosciences*, *83*(1), 17-31. https://doi.org/10.1017/S0016774600020436

Barron, A.P. (2015). *Palynological Interpretations of Deep Sea Drilling Projects Cores in the Gulf of Mexico and Bahamian Platform* [Master's thesis, Missouri University of Science and Technology]. Masters Theses, 7387. https://scholarsmine.mst.edu/masters_theses/7387

Brinkhuis, H. (1994). Late Eocene to Early Oligocene dinoflagellate cysts from the Priabonian type-area (northeast Italy): biostratigraphy and paleoenvironmental interpretation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *107*(1-2), 121-163. https://doi.org/10.1016/0031-0182(94)90168-6

Chowdhury, K. R. (1982). Distribution of Recent and fossil palynomorphs in the south eastern North Sea. *Senckenbergiana Maritima*, *14*(3-4), 79-145.

Dupont, L.M., & Agwu, C.O.C. (1991) Environmental control of pollen grain distribution patterns in the Gulf of Guinea and offshore NW-Africa. *Geologische Rundschau*, 80, 567-589. https://doi.org/10.1007/BF01803687

Farley, M. B., & Dilcher, D. L. (1986). Correlation between miospores and depositional environments of the Dakota Formation (Mid-Cretaceous) of North Central Kansas and adjacent Nebraska, USA. *Palynology*, 10 (1), 117-133. https://doi.org/10.1080/01916122.1986.9989306

Groot, J. J. (1966). Some observations on pollen grains in suspension in the estuary of the Delaware River. *Marine Geology*, *4*(6), 409-416. https://doi.org/10.1016/0025-3227(66)90009-0

Hardy, M. J., & Wrenn, J. H. (2009) Palynomorph distribution in modern tropical deltaic and shelf sediments– Mahakam Delta, Borneo, Indonesia. *Palynology*, *33*(2), 19-42. https://doi.org/10.1080/01916122.2009.9989681

Harris, A. J., & Tocher, B. A. (2003). Palaeoenvironmental analysis of Late Cretaceous dinoflagellate cyst assemblages using high-resolution sample correlation from the Western Interior Basin, USA. *Marine Micropaleontology*, *48*(1-2), 127-148. https://doi.org/10.1016/S0377-8398(03)00002-1

Heimhofer, U., Wucherpfennig, N., Adatte, T., Schouten, S., Schneebeli-Hermann, E., Gardin, S., Keller, G., Kentsch, S., & Kujau, A. (2018). Vegetation response to exceptional global warmth during Oceanic Anoxic Event 2. *Nature Communications*, *9*, 3832. https://doi.org/10.1038/s41467-018-06319-6

Heusser, L. E. (1985). Quaternary palynology of marine sediments in the northeast Pacific, northwest Atlantic, and Gulf of Mexico. In V. M. Bryant Jr & R. G. Holloway (Eds.). *Pollen Records of Late Quaternary North American Sediments* (pp. 385-404). American Association of Stratigraphic Palynologists Foundation.

Heusser, L. E. (1988). Pollen distribution in marine sediments on the continental margin off northern California. *Marine Geology*, *80*(1-2), 131-147. https://doi.org/10.1016/0025-3227(88)90076-X

Heusser, L. E., & Balsam, W. L. (1977). Pollen distribution in the northeast Pacific Ocean. *Quaternary Research*, *7*(1), 45-62. https://doi.org/10.1016/0033-5894(77)90013-8

Heusser, L. E., & Balsam, W. L. (1985). Pollen sedimentation in the northwest Atlantic: effects of the Western Boundary Undercurrent. *Marine Geology*, *69*(1-2), 149-153. https://doi.org/10.1016/0025-3227(85)90138-0

Lorente, M. A. (1986). *Palynology and palynofacies of the Upper Tertiary in Venezuela* [Ph.D dissertation]. Dissertationes Botanicae, Band 99. Lubrecht & Cramer Ltd., Port Jervis.

Lorente, M. A. (1990). Textural characteristics of organic matter in several subenvironments of the Orinoco upper delta. *Geologie en Mijnbouw*, *69*, 263-278.

http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=6901731Mudie, 1982

Mindata, (n.d.) https://www.mindat.org/min-3337.html

Muller, J. (1959). Palynology of Recent Orinoco Delta and shelf sediments: reports of the Orinoco Shelf expedition; volume 5. *Micropaleontology*, *5*(1), 1-32. https://doi.org/10.2307/1484153

Poumot, C. (1989). Palynological evidence for eustatic events in the tropical Neogene. *Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine*, *13*(2), 437-453. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=6632083

Sluijs, A., Pross, J., & Brinkhuis, H. (2005). From greenhouse to icehouse; organic-walled dinoflagellate cysts as paleoenvironmental indicators in the Paleogene. *Earth-Science Reviews*, *68*(3–4), 281-315. https://doi.org/10.1016/j.earscirev.2004.06.001

Speelman, J. D., & Hills, L. V. (1980). Megaspore Paleoecology: Parowki, Foremost, and Oldman Formations (Upper Cretaceous), Southeastern Alberta. *Bulletin of Canadian Petroleum Geology*, *28*(4), 522–541. https://doi.org/10.35767/gscpgbull.28.4.522

Stanley, E. A. (1965). Abundance of pollen and spores in marine sediments off the eastern coast of the United States. *Southeastern Geology*, *7*(1), 25-33. https://shorturl.at/tDH49

Streel, M., & Bless, J. M. (1980). Occurrence and significance of reworked palynomorphs. *Mededelingen Rijks Geologische Dienst*, 32(10), 69-80. https://shorturl.at/aBCF8

Tschudy, R. H. (1969). Relationship of palynomorphs to sedimentation. In R. H. Tschudy & R. A. Scott (Eds.). *Aspects of Palynology* (pp. 79-96). Wiley. https://search.worldcat.org/title/aspects-of-palynology/oclc/51371

Williams, D. B., & Sarjeant, W. A. S. (1967). Organic-walled microfossils as depth and shoreline indicators. *Marine Geology*, *5*(5–6), 389-412. https://doi.org/10.1016/0025-3227(67)90050-3

Winslow, M. R. (1962). Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. *USGS Professional Paper*, *364*, 1-93. https://doi.org/10.3133/pp364