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Supplement of

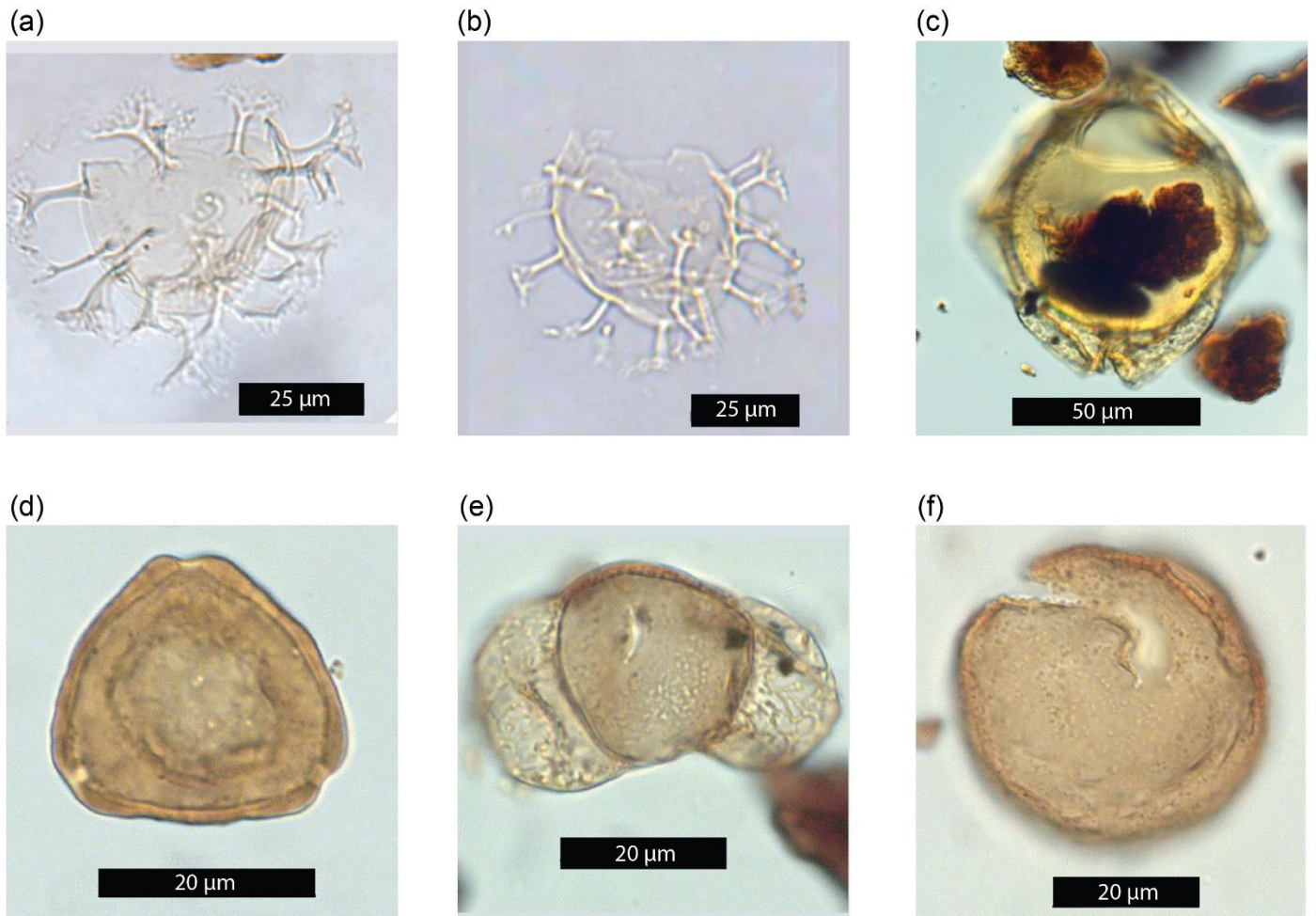
**Surface-circulation change in the southwest Pacific Ocean across
the Middle Eocene Climatic Optimum: inferences from
dinoflagellate cysts and biomarker paleothermometry**

Margot J. Cramwinckel et al.

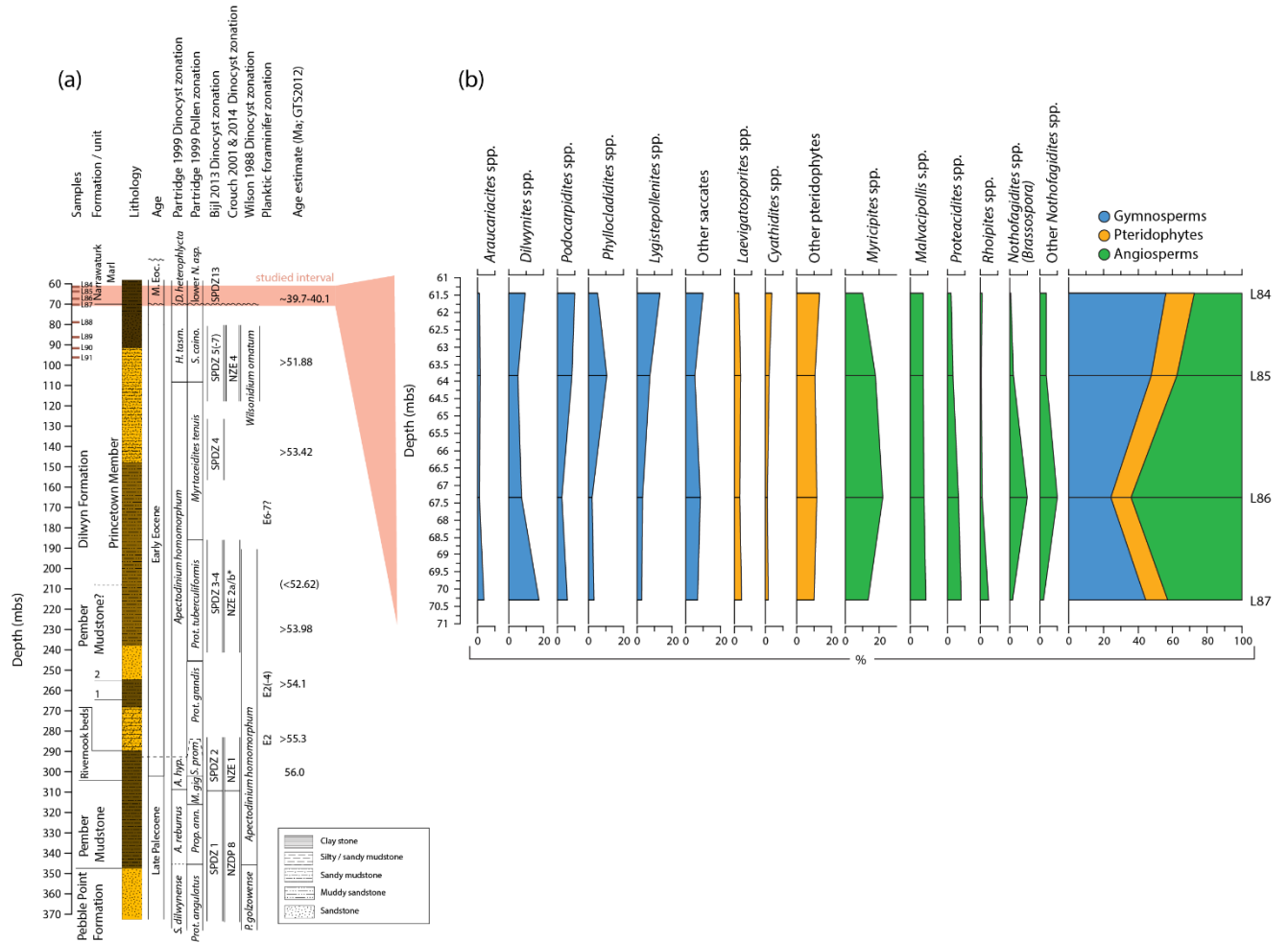
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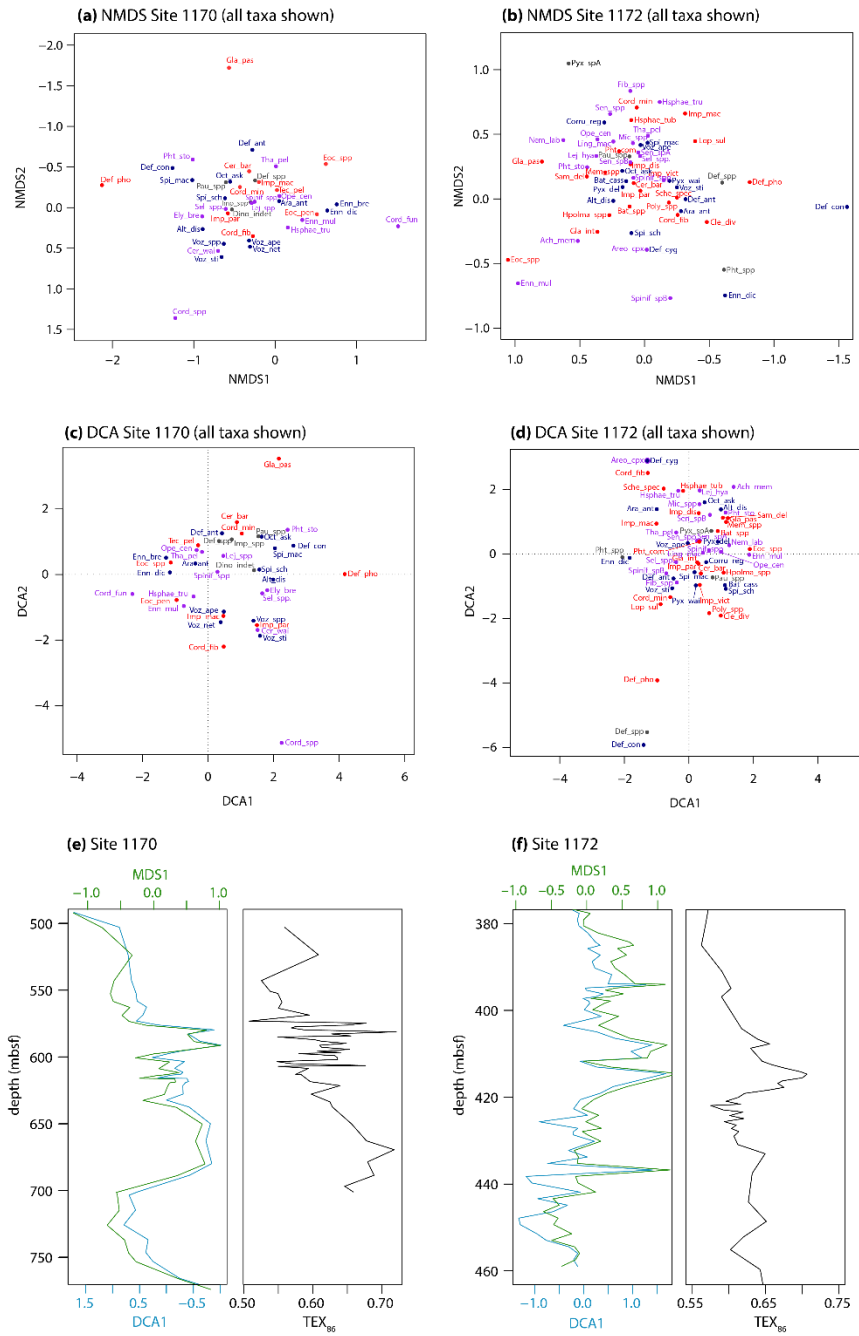
Supplementary Figures



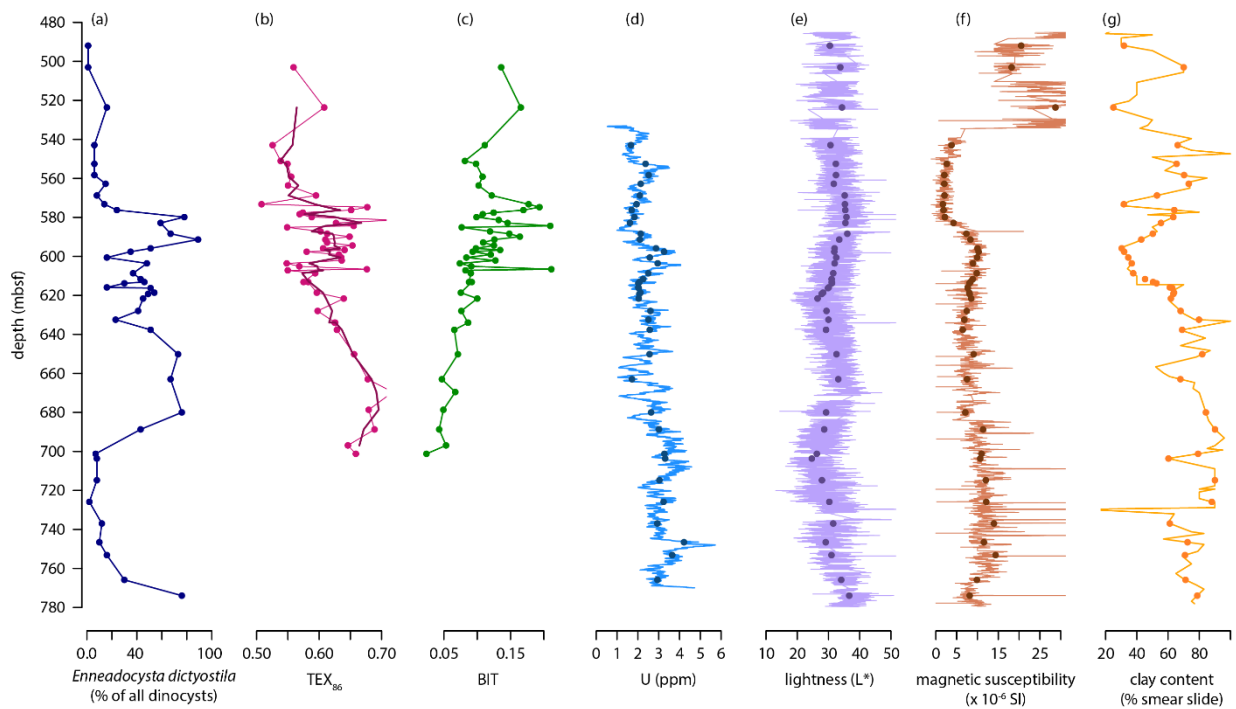
Supplementary Figure 1. Plate with light microscope images of relevant palynomorphs encountered in this study. **(a)** Dinocyst *Enneadocysta dictyostila* from sample 1170D 21R 4W 85-87 cm (EFC unavailable), scale bar 25 µm. **(b)** Dinocyst *Enneadocysta multicornuta* from sample 1170D 23R 2W 85-87 cm (EFC unavailable), scale bar 25 µm. **(c)** Dinocyst *Dracodinium rhomboideum* from sample L86 slide 2 (EFC E48.1), scale bar 50 µm. **(d)** Pollen *Myricipites harrisii* from sample L85 slide 1 (EFC J15.4), scale bar 20 µm. **(e)** Pollen *Podocarpidites ellipticus* from sample L84 slide 1 (EFC G19.2), scale bar 20 µm. **(f)** Pollen *Dilwynites granulatus* from sample L87 slide 1 (EFC J16.1), scale bar 20 µm.



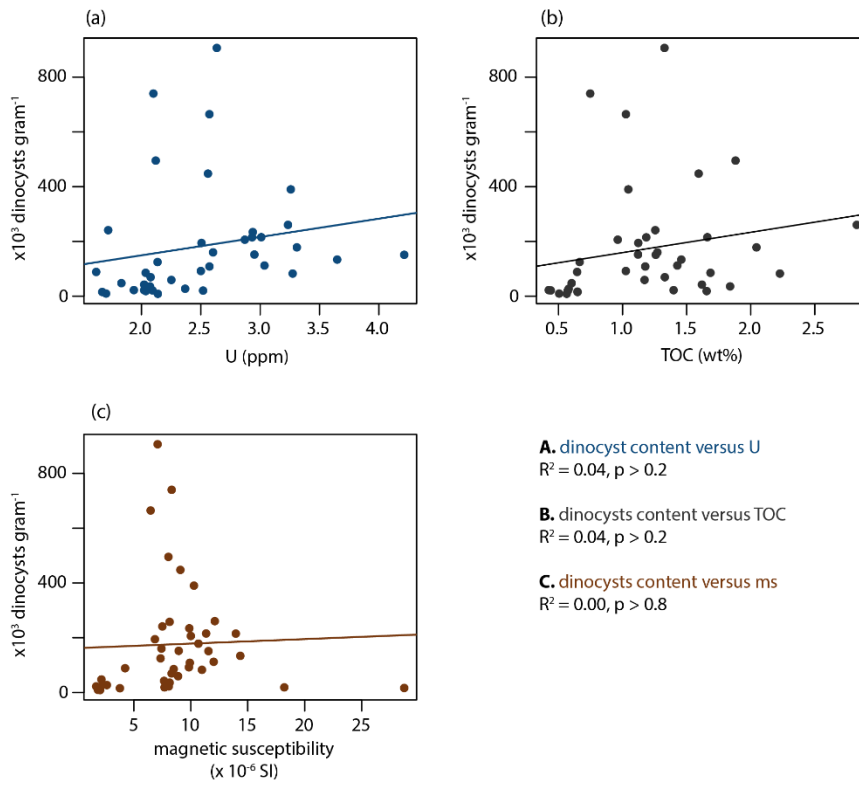
Supplementary Figure 2. (a) Stratigraphy of the Latrobe-1 borehole, including studied samples, lithologic units, lithology and age constraints based on microfossil biostratigraphy. The interval analysed in this study is highlighted in pink. Figure adapted from (Frieling et al., 2018a). (b) Relative abundances of representative sporomorph taxa in samples L84-L87 from the Latrobe-1 borehole, in percentage of total sporomorph assemblage.



Supplementary Figure 3. Additional ordination results. Nonmetric multidimensional scaling (NMDS) ordination diagram for the dinocyst assemblage data of Site 1170 (a) and Site 1172 (b). Detrended correspondence analysis (DCA) ordination diagram for the dinocyst assemblage data of Site 1170 (c) and Site 1172 (d). Species scores in a-d as circles, colour-coded by biogeographic affinity (red, mid-low latitude; purple, cosmopolitan; blue, endemic; grey, not assigned). Full names for dinocyst abbreviations can be found in the Supplementary Datafile. First axis of DCA (blue) and NMDS (green) analysis of Site 1170 (e) and Site 1172 (f), together with the respective TEX₈₆ records (black).



Supplementary Figure 4. Environmental proxy records over the MECO interval of Site 1170, as used in CCA analysis (b-g). Original data plotted as line, data interpolated to depth of dinocyst samples plotted as dots. Plotted against depth in metres below sea level. **(a)** Relative abundance of *Enneadocysta dictyostila* (percentage of total dinocyst assemblage; dark blue dots and line). **(b)** TEX_{86} (pink dots and line), with three-point moving average (purple lines). **(c)** BIT (green dots and line). **(d)** Sedimentary uranium content (ppm; blue dots and line). **(e)** Spectrophotometric lightness (CIELAB L^* ; purple dots and line). **(f)** Core-measured magnetic susceptibility ($\times 10^{-6}$ SI). **(g)** Clay content (% of smear slide). Data in panels d-g from Exon et al. (2001).



Supplementary Figure 5. Scatter plots and regression analysis of sedimentary dinocyst content as a function of selected proxy records of Site 1170, indicating no significant correlation. **(a)** Dinoflagellate cyst content (cysts per gram of dry sediment) against uranium content (ppm). **(b)** Dinoflagellate cyst content (cysts per gram of dry sediment) against total organic carbon content (weight percentage). **(c)** Dinoflagellate cyst content (cysts per gram of dry sediment) against magnetic susceptibility ($\times 10^{-6}$ SI). U, TOC and ms data from Exxon et al. (2001).

Supplementary Table 1. List of observed dinoflagellate cyst species, including their biogeographic affinity as used in the present study (bg1), an alternative biogeographic grouping (bg2), cyst type, and at which of the studied sites (Site 1170, Site 1172, Latrobe-1 borehole, Hampden Beach section) they were encountered. Abbreviations: g, gonyaulacoid; p, peridinioid; m, mid-/low-latitude; c, cosmopolitan; b, bipolar; tf, endemic "Transantarctic Flora"; e, endemic Southern Ocean; o, other (unknown or ambivalent); wetz, wetzelellioids (here considered cosmopolitan, could also be considered mid-/low-latitude based on their warm affinity); gonio, goniodomids.

dinocyst taxon	abbreviation	bg1	bg2	cyst	1170	1172	Latrobe	Hampden
<i>Achilleodinium biformoides</i>	Ach_bi	c	c	g			Latrobe	
<i>Achomospaera membraniphora</i>	Ach_mem	c	c	g		1172		
<i>Achomospaera ramulifera</i>	Ach_ram	c	c	g		1172		
<i>Achomospaera</i> spp. (pars)	Ach_spp	c	c	g			Latrobe	Hampden
<i>Adnatosphaeridium</i> spp.	Ad_spp	c	c	g			Latrobe	
<i>Alisocysta circumtabulata</i>	Ali_cir	c	c	g				Hampden
<i>Alterbidinium acutum</i>	Alt_acu	e	e	p		1172		
<i>Alterbidinium distinctum</i>	Alt_dis	tf	tf	p	1170	1172		
<i>Apectodinium homomorphum</i>	Ape_hom	wetz	m	p		1172		
<i>Apteodinium australiense</i>	Apt_aus	m	m	g		1172		
<i>Arachnodinium antarcticum</i>	Ara_ant	tf	tf	g	1170	1172		
<i>Areoligera</i> Cpx. (pars)	Areo_cpx	c	c	g		1172	Latrobe	
<i>Batiacasphaera cassicula</i>	Bat_cass	e	e	g		1172		Hampden
<i>Batiacasphaera</i> spp.	Bat_spp	m	m	g		1172	Latrobe	
<i>Brigantedinium</i> spp.	Brig_spp	c	c	p		1172		
<i>Cerebrocysta bartonensis</i>	Cer_bar	m	m	g	1170	1172		
<i>Cerebrocysta</i> spp. (pars)	Cer_spp	c	c	g		1172		
<i>Cerebrocysta waipawaensis</i>	Cer_wai	c	c	g	1170			Hampden
<i>Charlesdowniea coleothrypta</i>	Char_col	wetz	c	p		1172		
<i>Cleistosphaeridium diversispinosum</i>	Cle_div	m	m	g		1172		
<i>Cleistosphaeridium placacanthum</i>	Cle_pla	m	m	g		1172		
<i>Cleistosphaeridium</i> spp. (pars)	Cle_spp	c	c	g			Latrobe	Hampden
<i>Cordosphaeridium</i> Cpx. (pars)	Cord_spp	c	c	g	1170		Latrobe	
<i>Cordosphaeridium fibrospinosum</i>	Cord_fib	m	m	g	1170	1172	Latrobe	Hampden
<i>Cordosphaeridium funiculatum</i>	Cord_fun	c	c	g	1170			
<i>Cordosphaeridium minimum</i>	Cord_min	m	m	g	1170	1172		
<i>Corrudinium incompositum</i>	Cor_inc	m	m	g	1170		Latrobe	
<i>Corrudinium regulare</i>	Corru_reg	tf	tf	g		1172		
<i>Corrudinium</i> spp. (pars)	Corru_spp	o	o	g			Latrobe	
<i>Cribroperidinium</i> spp. (pars)	Cri_spp	c	c	g		1172		

<i>Cribroperidinium tenuitabulatum</i>	Cri_ten	c	c	g				Hampden
<i>Danea crassimurata</i>	Dan_cra	c	c	g				Hampden
<i>Dapsilidinium</i> spp.	Daps_spp	m	m	g		1172	Latrobe	Hampden
<i>Deflandrea antarctica</i>	Def_ant	tf	tf	p	1170	1172		Hampden
<i>Deflandrea convexa</i>	Def_con	tf	tf	p	1170	1172		
<i>Deflandrea cygniformis</i>	Def_cyg	tf	tf	p	1170	1172		
<i>Deflandrea phosphoritica</i>	Def_pho	m	m	p	1170	1172	Latrobe	
<i>Deflandrea</i> sp. A cf. Brinkhuis 2003	Def_spA	tf	tf	p		1172		
<i>Deflandrea</i> spp. (pars)	Def_spp	o	o	p	1170	1172	Latrobe	
<i>Diphyes colligerum</i>	Diph_col	c	c	g		1172		Hampden
<i>Diphyes</i> spp. (pars)	Diph_spp	c	c	g			Latrobe	
<i>Distatodinium ellipticum</i>	Dis_ell	m	m	g			Latrobe	
<i>Distatodinium paradoxum</i>	Dis_par	m	m	g		1172	Latrobe	
<i>Dracodinium rhomboideum</i>	Dra_rho	wetz	c	p			Latrobe	
<i>Elytrocysta brevis</i>	Ely_bre	c	c	g	1170			Hampden
<i>Enneadocysta brevistila</i>	Enn_bre	tf	tf	g	1170			
<i>Enneadocysta dictyostila</i>	Enn_dic	tf	tf	g	1170	1172		Hampden
<i>Enneadocysta multicornuta</i>	Enn_mul	c	c	g	1170	1172	Latrobe	
<i>Enneadocysta pectiniformis</i>	Enn_pec	m	m	g			Latrobe	
<i>Enneadocysta</i> spp. (pars)	Enn_spp	o	o	g			Latrobe	
<i>Enneadocysta-Oligosphaeridium</i> intermediate	Enn_Oli	o	o	g			Latrobe	
<i>Eocladopyxis peniculata</i>	Eoc_pen	gonio	m	g	1170			
<i>Eocladopyxis</i> spp. (pars)	Eoc_spp	gonio	m	g	1170	1172	Latrobe	Hampden
<i>Fibrocysta</i> spp.	Fib_spp	c	c	g		1172		Hampden
<i>Gelatia inflata</i>	Gel_inf	b	b	g		1172		
<i>Glaphyrocysta delicata</i>	Gla_del	m	m	g		1172		Hampden
<i>Glaphyrocysta intricata</i>	Gla_int	m	m	g		1172		
<i>Glaphyrocysta pastielsii</i>	Gla_pas	m	m	g	1170	1172		
<i>Glaphyrocysta retiintexta</i>	Gla_ret	m	m	g		1172		
<i>Hemiplacophora semilunifera</i>	Hem_sem	c	c	g			Latrobe	
<i>Heteraulacacysta</i> spp.	Het_spp	gonio	c	g			Latrobe	Hampden
<i>Homotryblium</i> spp.	Hom_spp	gonio	c	g	1170			
<i>Hystiocysta / Elytrocysta</i> spp. (pars)	Hcyst_Ely	c	c	g		1172	Latrobe	Hampden
<i>Hystrichokolpoma rigaudiae</i>	Hpolma_rig	m	m	g		1172		Hampden
<i>Hystrichokolpoma spinosum</i>	Hpoma_spi	m	m	g		1172		
<i>Hystrichokolpoma</i> spp. (pars)	Hpolma_spp	m	m	g		1172	Latrobe	
<i>Hystrichokolpoma truncatum</i>	Hpolma_tru	m	m	g		1172		
<i>Hystrichosphaeridium truswelliae</i>	Hsphae_tru	c	c	g	1170	1172		

<i>Hystrichosphaeridium tubiferum</i>	Hsphae_tub	m	m	g		1172	Latrobe	Hampden
<i>Impagidinium dispertitum</i>	Imp_dis	m	m	g		1172		Hampden
<i>Impagidinium maculatum</i>	Imp_mac	m	m	g	1170	1172		Hampden
<i>Impagidinium parvireticulatum</i>	Imp_par	m	m	g	1170	1172		
<i>Impagidinium</i> spp. (pars)	Imp_spp	o	o	g	1170	1172	Latrobe	
<i>Impagidinium victorianum</i>	Imp_vict	m	m	g		1172		
<i>Kallosphaeridium</i> spp.	Kal_spp	c	c	g		1172	Latrobe	
<i>Lejeunecysta hyalina</i>	Lej_hya	c	c	p		1172		
<i>Lejeunecysta</i> spp. (pars)	Lej_spp	c	c	p	1170		Latrobe	Hampden
<i>Lingulodinium machaerophorum</i>	Ling_mac	c	c	g		1172		
<i>Lingulodinium</i> spp. (pars)	Ling_spp	c	c	g			Latrobe	
<i>Lophocysta sulcolimbata</i>	Lop_sul	m	m	g	1170	1172		
<i>Melitasphaeridium pseudorecurvatum</i>	Mel_pseu	c	c	g			Latrobe	Hampden
<i>Membranosphaera</i> spp.	Mem_spp	m	m	g		1172		
<i>Microdinium</i> spp.	Mic_spp	c	c	g		1172		
<i>Nematosphaeropsis labyrinthus</i>	Nem_lab	c	c	g		1172		
<i>Octodinium askiniae</i>	Oct_ask	tf	tf	p	1170	1172		Hampden
<i>Operculodinium centrocarpum</i>	Ope_cen	c	c	g	1170	1172		
<i>Operculodinium</i> spp. (pars)	Oper_spp	c	c	g		1172	Latrobe	Hampden
<i>Paucisphaeridium</i> spp.	Pau_spp	o	o	o	1170	1172		Hampden
<i>Pentadinium</i> spp.	Pen_spp	c	c	g			Latrobe	
<i>Phthanoperidinium comatum</i> **	Pht_com	c	c	p		1172	Latrobe	
<i>Phthanoperidinium</i> spp. (pars)	Pht_spp	o	o	p		1172	Latrobe	
<i>Phthanoperidinium stockmansii</i> **	Pht_sto	c	c	p	1170	1172		Hampden
<i>Polysphaeridium</i> spp.	Poly_spp	gonio	m	g		1172		Hampden
<i>Protoperidinium</i> sp. A*	Proto_spA	?	?	p		1172		
<i>Pyxidinopsis delicata</i>	Pyx_del	e	e	g		1172		Hampden
<i>Pyxidinopsis</i> sp. A*	Pyx_spA	?	?	g		1172		
<i>Pyxidinopsis waipawaensis</i>	Pyx_wai	e	e	g		1172		
<i>Reticulatosphaera actinocoronata</i>	Ret_act	c	c	g		1172		
<i>Rhombodinium rhomboideum</i>	Rho_rho	wetz	c	p				Hampden
<i>Rhombodinium</i> spp.	Rho_spp	wetz	c	p		1172		
<i>Samlandia septata</i>	Sam_del	m	m	g		1172		Hampden
<i>Schematophora speciosa</i>	Sche_spec	m	m	g		1172		
<i>Selenopemphix</i> spp.	Sel_spp.	c	c	p	1170	1172		
<i>Senegalinium</i> sp. A brown	Sen_spA	c	c	p		1172		
<i>Senegalinium</i> sp. B transparent	Sen_spB	c	c	p		1172		

<i>Senegalinium</i> spp. (pars)	Sen_spp	c	c	p		1172	Latrobe	Hampden
<i>Spinidinium colemanii</i>	Spi_col	m	m	p	1170			
<i>Spinidinium macmurdoense</i>	Spi_mac	b	b	p	1170	1172		Hampden
<i>Spinidinium schellenbergii</i>	Spi_sch	tf	tf	p	1170	1172		Hampden
<i>Spiniferites pseudofurcatus</i> - type	Spi_pseu	c	c	g			Latrobe	
<i>Spiniferites ramosus</i>	Spinif_ram	c	c	g		1172		
<i>Spiniferites</i> sp. B cf. Brinkhuis 2003	Spinif_spB	c	c	g		1172		
<i>Spiniferites</i> spp. (pars)	Spinif_spp	c	c	g	1170	1172	Latrobe	Hampden
<i>Stoveracysta kakanuensis</i>	Sto_kak	e	e	g		1172		
<i>Stoveracysta ornata</i>	Sto_orn	c	c	g		1172		
<i>Stoveracysta</i> spp. (pars)	Sto_evi	c	c	g				Hampden
<i>Tectatodinium pellitum</i>	Tec_pel	m	m	g	1170		Latrobe	
<i>Thalassiphora pelagica</i>	Tha_pel	c	c	g	1170	1172		
<i>Thalassiphora</i> spp. (pars)	Tha_spp	c	c	g			Latrobe	
<i>Turbiosphaera filosa</i>	Turb_fil	m	m	g		1172		
<i>Vozzhennikovia apertura</i>	Voz_ape	b	b	p	1170	1172		Hampden
<i>Vozzhennikovia netrona</i>	Voz_net	tf	tf	p	1170	1172		
<i>Vozzhennikovia</i> spp. (pars)	Voz_spp	b	b	p	1170			
<i>Vozzhennikovia stickleyae</i>	Voz_sti	tf	tf	p	1170	1172		
<i>Wetzellioid</i> indet.	Wetz_spp	wetz	c	p			Latrobe	
<i>Wilsonidium echinosuturatum</i> **	Wil_ech	wetz	c	p		1172		Hampden
<i>Wilsonidium ornatum</i>	Wil_orn	wetz	m	p		1172		
Dinocyst indet.	Dino_indet	o	o	o	1170			
Dinocyst G-cyst indet.	Gcyst_indet	o	o	g			Latrobe	
Dinocyst P-cyst indet.	Pcyst_indet	o	o	p				

* uncertain biogeographic affinity

** based on in prep. dinocyst results from IODP Site U1408 and U1410