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Composite *Phymatoderma* from Neogene deep-marine deposits in Japan: Implications for Phanerozoic benthic interactions between burrows and the trace-makers of *Chondrites* and *Phycosiphon*

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Supplementary Online Material

Table. Phanerozoic records of trace fossils (or modern traces) that were reworked by *Chondrites* and *Phycosiphon*.

References

Table. Phanerozoic records of trace fossils (or modern traces) that were reworked by Chondrites and Phycosiphon.

Reworked by *Chondrites*						
Age	Formation or section/Locality	Lithology/Depositional setting	Reworked trace fossil	Burrow diameter of reworked materials (mm)	Reference	Note
Modern	various regions such as outer Bengal Fan area	various modern sediments/deep-sea (water depth greater than 500-1000 m)	*Planolites*	2-15	Wetzel 1991	
Quaternary	Krishna-Godavari basin/Bay of Bengal	cold-seep carbonate/continental slope	pellet-filled branched burrows	4-17	Mazumdar et al. 2011	
Pliocene-Pleistocene	British Geological Survey Borehole 88/7 /Hebrides Slope	muds and sandy muds with rare dropstones/anomalous, difficult to interpret	*Planolites*	11.43	Leslie 1993	diameter not described, but measured using fig. 9
Pliocene	Shiramazu Formation/Japan	alternations of tuffaceous sandstones and siltstones/continental slope	*Phymatoderma*	8.30-30.95	Izumi in press	
middle Miocene	Pebas Formation/Peru	mud, sand, lignite, and shell bed/tidally-influenced, brackish water	*Planolites*	less than 2	Gingras et al. 2002	
early Miocene	Chenque Formation/Argentina	sandy, muddy, and tuffaceous/tidal bars, subtidal bars, shoreface	*Helicodromites mobilis* *Gyrolithes* *Teichichnus zigzag* *Thalassinoides*	2.6-3.2 (smaller) 5.4-9.8 (larger) 45-65 10-12 17-76	Carmona et al. 2008	
middle Eocene	Ainsa Basin/Spain	thin-bedded siliciclastic turbidites/deep-sea	*Planolites* *Thalassinoides*	3-7 5-20	Heard et al. 2008	

middle Eocene	Scaglia Toscana Formation/Italy	fine-grained siliciclastic, carbonate, and bioclastic turbidites/deep-sea	*Palaeophycus*	10-20	Monaco et al. 2012	
Paleocene-Eocene	Itzurun Formation/Spain	alternations of limestones, marly limestones and marls, with intercalations of turbidite/between middle and lower bathyal environments, at about 1000 m water depth	*Planolites*	4-5	Rodríguez-Tovar et al. 2011b	
			Zoophycos	3-4		marginal tunnel diameter
late Paleocene	Zumaya section/Spain	alternating limestones, calcareous turbidites, and siliceous sandstones/deep-marine at water depth of ca. 1000 m	*Palaeophycus tubularis* form A	20 or larger than 20	Giannetti and McCann 2010	
			Palaeophycus tubularis form B	less than 20		
			Planolites montanus	ca. 5		
			Thalassinoides suevicus	5-15		
			Zoophycos brianteus	50-350		diameter of the whole structure, not diameter of marginal tube
late Paleocene	Scaglia Cinerea unit/Italy	interbedded biomicrite and calcareous mudstone or marl/bathyal depth	*Zoophycos* isp. form A	not described	Miller 2001	
			Thalassinoides-Phycodes compound system	3-10		
Cretaceous/ Paleogene	Jorquera Formation/Spain	marls and marly limestones/middle bathyal at water depth 600-1000 m	*Thalassinoides*	10-20	Rodríguez-Tovar and Uchman 2006	
			turbular burrow	10		
Cretaceous/ Paleogene	Bidart section/France Sopelana section/Spain	hemipelagites and turbidites/water depth ranging from 1000 to 1500 m	*Planolites*	2.5-4	Rodríguez-Tovar et al. 2011a	
			Thalassinoides	4-9 (smaller) 15-30 (larger)		

late Maastrichtian	Rørdal Member/Denmark	cyclic chalk-marl succession/below storm wave base with water depth of probably several hundreds meters	*Thalassinoides*	15-25	Lauridsen et al. 2011	
late Maastrichtian	Dania Quarry/Denmark	chalk/shallow-water chalk	probably *Thalassinoides*	7.25	Bromley and Ekdale 1984b	diameter not described, but measured using fig. 5
late Maastrichtian	Dania Quarry/Denmark	chalk/shelf-sea	*Thalassinoides*	-	Ekdale and Bromley 1991	diameter not described, and difficult to measure using a published figure
late Campanian-Maastrichtian	Monte Antola Formation/Italy	carbonate-siliciclastic flysch/deep-sea below the calcite compensation depth (CCD)	*Planolites beverleyensis* morphotype B	ca. 5	Uchman 2007	
			?*Radhostium* isp.	3-10		
Campanian-early Maastrichtian	Ropianka Formation/Poland	thin-bedded marlstones interbedded with muddy to clayey shales and thin-bedded sandstones/trough-type deep-sea basin	*Planolites*	1.5-5	Leszczyński 2004	
Santonian-Maastrichtian	Wyandot Formation/offshore Nova Scotia	fine-grained calcareous mudstone/outer shelf to upper bathyal setting	*Thalassinoides*	12-40	Phillips and McIlroy 2010	
Cenomanian-Maastrichtian	Chalk unit/northen Europe	chalk/not described	*Thalassinoides*	-	Bromley and Ekdale 1984a	diameter not described
early Campanian	Province de Liége/Belgium	smectite/not described	*Gyrolithes davreuxi*	ca. 1	Bromley and Frey 1974	diameter of burrow walls

late Turonian-late Santonian	Piesenkopf-Schichten/Austria and Germany	thin-bedded turbiditic flysch composed of sandstone-limestone;marlstone/deep-sea	*Planolites beverleyensis*	3-8	Uchman 1999	
Turonian-Coniasian	Opole region/Poland	marlstone dominated/outer shelf (below storm wave base)	*Planolites* *Thalassinoides*	2-6 12-25	Kędzierski and Uchman 2001	
Cenomanian-Turonian	Capas Blancas Formation/Spain	marly limestones and marls with chert nodules and beds/moderately deep pelagic plateau	*Thalassinoides*	6-11	Rogríguez-Tovar et al. 2009	
Cenomanian-Turonian	Rybie section/Poland	marl dominated/submarine high	*Planolites*	2.5-4.5	Uchman et al. 2013a	
Cenomanian-Turonian	Bonarelli Level/Poland	cherty limestones intercalated with black shales, gray marly shales and non-calcareous shales/pelagic and hemipelagic, beyond tha range of gravitational flows	*Thalassinoides*	7-18	Uchman et al. 2013b	
middle Cenomanian	The Chalk Marl/UK	limestones, separated by marly shalk/not described	*Thalassinoides*	-	Gale 1989	diameter not described
Late Cretaceous	Resspass/ Switzerland	calcareous turbidite/deep-sea	? (= it cannot be observed today)	?	Uchman and Wetzel 1999	
Aptian-Albian	Kotick Point Formation/Antarctica	alternations of breccia, conglomerates, sandstones and mudstones/continental slope	*Cladichnus fischeri*	2-5	Buatois and Mángano 1992	
Hauterivian	Bouvières section/France	interbedded calcareous mudstone and marlstone/deep-marine	*Halimedides*	0.5-2.5	Gaillard and Olivero 2009	
Cretaceous	Unterpurkersdorf at Wien	not described/not described	? (= Bandchondriten)	6.09, 6.40	Fu 1991	not described, but measured using plate 3, photos A-B

Pliensbachian	Calcari Grigi Formation/Italy	massive to well-bedded limestones and marls/shallow-water carbpnate platform	*Ophiomorpha irregularie*	20-40	Monaco and Garassino 2001	
Sinemurian/ Pliensbachian	Calcari Grigi Formation/Italy	massive to well-bedded limestones and marls/shallow-water, oceanic carbonate platform	*Ophiomorpha nodosa*	30-50	Monaco and Giannetti 2002	
Sinemurian	Bishopsworth/UK	dark shale/not described	*Corophioides*	7-8	Simpson 1957	U-tunnel diameter
?Sinemurian	Blue Lias and Charmouth Mudstone Formations/UK	interbedded mudstones and limestones with distinctive marker beds/?shallow shelf environment	*Planolites*	15	Gallois and Paul 2009	age and depositional setting of the studied succession (highest part of the Blue Lias Formation to the lowest part of the Charmouth Mudstone Formation) are not describedBlue Lias Formation: Hettangian-Sinemurian Charmouth Mudstone Formation: Sinemurian-lower Pliensbachian
Hettangian-Simenurian	Blue Lias Formation/UK	rhythmically bedded black shales and marls (sometimes limestones)/shallow shelf paleoenvironment	*Thalassinoides*	10-40	Moghadam and Paul 2000	
Middle Triassic	Bravaisberget and Botneheia Formations/Svalbard	dark organic-rich shale/deltaic to restricted shelf	*Thalassinoides*	10-50	Mørk and Bromley 2008	
Early Pensilvanian-Early Permian	Oquirrh Formation/US	not described/controversial (shallow vs. deep)	*Spirophycus*	3-5	Ekdale and Mason 1988	diameter not described, but measured using fig. 2C and F
Early Pensilvannian	Morrow Sandstone/US	very fine-grained silty sandstone and siltstone/distal lower-shoreface	*Alenicorites*	ca. 1.5	Buatois et al. 2002	diameter not described, but measured using fig. 8C
Late Ordovician	Yeoman Formation/Canada	carbonate-evaporite cycles/marine shelf	*Trypanites*	a few mm to a few cm	Pak et al. 2010	depositional setting from Li et al. 2001
			Thalassinoides	a few mm to a few cm		

Reworked by *Phycosiphon*

Age	Formation or section/Locality	Lithology/Depositional setting	Reworked trace fossil	Burrow diameter of reworked materials (mm)	Reference	Note
Modern	off NW Africa	modern deposits/bathyal	*Planolites*	11.25, 13.75	Wetzel 2010	diameter not described, but measured using Text-fig. 4-2
Pliocene	Shiramazu Formation/Japan	alternations of tuffaceous sandstones and siltstones/continental slope	*Phymatoderma*	9.70-40.65	Izumi in press	
early Miocene	Chenque Formation/ Argentina	sandy, muddy, and tuffaceous/tidal bars, subtidal bars, shoreface	*Thalassinoides*	17-76	Carmona et al. 2008	
late Maastrichtian	Dania Quarry/Denmark	chalk/shalf-sea	*Thalassinoides*	-	Ekdale and Bromley 1991	diameter not described, and difficult to measure using a published figure/reworked by *Anconichnus*
			?*Thalassinoides*	-		diameter not described, and difficult to measure using a published figure/reworked by *Anconichnus*
			Zoophycos	8		diameter of vertical shaft, but *Anconichnus*-animal has meticulously avoided the shaft
Maastrichtian	López de Bertodano Formation/ Antarctica	mudstones and sandstones, glauconite-rich sandstones and mudstomes, sandy siltstones/shallow-marine	*Euflabella multiplex*	8-15	Olivero and Lopez Cabrera 2013	final tube diameter
late Campanian	Snow Hill Island Formation/ Antarctica	mudstones and sandstones with hummocky cross-stratification/ shallow -marine	*Euflabella multiplex*	8-15	Olivero and Lopez Cabrera 2013	final tube diameter

Turonian-Coniacian	Opole region/ Poland	marlstone dominated/outer shelf (below storm wave base)	*Thalassinoides*	12-25	Kędzierski and Uchman 2001	
late Cenomanian-middle Turonian	Stołowe Mountains/ Poland	conglomerates, sandstones, siliceous mudstones with spongiolite, glauconitic sandstone/ shelf bellow the wave-base	*Thalassinoides*	7-35	Rotnicka 2005	
			Ophiomorpha	-		diameter not described/reworked by *Anconichnus horizontalis* or *Helminthopsis*
late Albian	Viking (Bow Island) Formation/ Canada	rippled very fine-grained sandstones, siltstone and shale, low-angle laminated fine-grained sandstones/ storm-dominated delta front or lower shoreface	*Planolites*	11.25	Raychaudhuri and Pemberton 1992	diameter not described, but measured using fig. 6H/reworked by *Anconichnus horizontalis* or *Helminthopsis*
			Thalassinoides	14.04-24.17		diameter not described, but measured using fig. 6F, 8A, and 8D/reworked by *Anconichnus horizontalis* or *Helminthopsis*
Cretaceous	Norwegian sector/North Sea	highly argillaceous/outer shelf	*Teichicunus*	-	Bromley 1996	diameter not described, and difficult to measure using a published figure
		highly argillaceous/outer shelf	*Thalassinoides*	-	Bromley 1996	diameter not described, and difficult to measure using a published figure
Jurassic	Norwegian sector/North Sea	not described/inner shelf	*Teichichnus*	-	Bromley 1996	diameter not described, and difficult to measure using a published figure

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