Supplementary Material

1 Supplementary Data

The type descriptions of taxa recorded here can be accessed in the *Catalogue of Foraminifera* (published on-line by Micropaleontology Press) or in the *World Register of Marine Species* (www.marinespecies.org) by searching the species-level and author's names for species, and the genus-level name for genera.

Sample FPC-15 D5 S1 (1602 m): The planktonic foraminiferal assemblage is dominated by species of *Subbotina* Brotzen and Pożaryska. *Globanomalina* Haque is common; *Acarinina* Subbotina and *Morozovell*a McGowran are rare. The co-occurrence of *Globanomalina pseudomenardii* (Bolli) and *Acarinina soldadoensis* (Brönnimann) suggests that this sample belongs to planktonic foraminiferal Zone P4c, Late Paleocene (~56–56.5 Ma) (Olsson et al., 1999). Among the benthic foraminifera, the presence of abundant *Bulimina tuxpamensis* Cole associated with *Spiroplectammina spectabilis* (Grzybowski), *Oridorsalis umbonatus* (Reuss), *Osangularia* Brotzen, and *Pleurostomella* Reuss suggests that the depositional water depth was in the bathyal zone between about 200 m and 700 m following the bathymetric distribution model of van Morkhoven et al. (1986). There is no evidence of down-slope movement of sediment from a neritic shelf environment.

Sample FPC-D5 S8 (1241.1 m): The foraminifera are poorly preserved in this sample that has incipient cement. The presence of *Globigerinatheka index* (Finlay) together with probable *G. subconglobata* (Shutskaya) and very rare minute *Acarinina* sp. with some resemblance to *A. topilensis* (Cushman), suggest a probable E10–E12 zonal placement, Middle Eocene (~40–44 Ma) (Pearson et al. 2006). Few benthic foraminifera were recorded, but these are consistent with an upper bathyal depositional water depth. There is no evidence of down-slope movement of sediment from a neritic shelf environment.

Sample FPC-D7 S5 (1032 m): This is an indurated wackestone with scattered planktonic foraminifera and rare benthic types. Sponge spicules are abundant. The planktonic foraminifera are difficult to identify in random thin section, but include *Globigerinatheka* Brönnimann that indicate a Middle or Late Eocene age (zones E8–E16; ~34–48 Ma). The absence of distinct *Acarinina* or *Morozovelloides* Pearson and Berggren may indicate an age no older than zone E12, late Middle Eocene (no older than ~ 40 Ma) as does its position above sample FPC-D05 S008. There is no evidence of down-slope movement of sediment from a neritic shelf environment.

Samples FPC-15 D9 (S1), D9 (S2 and S4), D8 (S3) 746 m to 700 m: These samples contain foraminifera of variable preservation and seem to be the same age. The presence of *Catapsydrax dissimilis* (Cushman and Bermúdez), *C. unicavus* Bolli, Loeblich and Tappan, *Ciperoella anguliofficinalis* (Blow), G*loboturborotalita ouachitaensis* (Howe and Wallace), and *Dentoglobigerina tripartita* (Koch) and the absence of *Globigerinatheka, Hantkenina* Cushman, and *Turborotalia cerroazulensis* (Cole) characteristic of the Late Eocene and *Globigerinoides* Cushman characteristic of the Miocene, suggest that the samples belong within the Oligocene. The absence of abundant *Ciperoella* Olsson and Hemleben, including the *C. ciperoensis* (Bolli) group of species, and of *Dentoglobigerina binaiensis* (Koch) suggest that the age is early Oligocene (zone O1–2; ~ 30–33 Ma;Wade et al. 2018). The benthic foraminiferal assemblage is consistent with an upper bathyal to upper middle bathyal water depth (within the range 200–700 m) following the distributions cited by van Morkhoven et al. (1986). There is no evidence of down-slope movement of sediment from a neritic shelf environment.

References

Olsson, R.K., Hemleben, C., Berggren, W.A., Huber, B.T., 1999. Atlas of Paleocene planktonic foraminifera. Smithsonian Contributions to Paleobiology 85, 1–252.

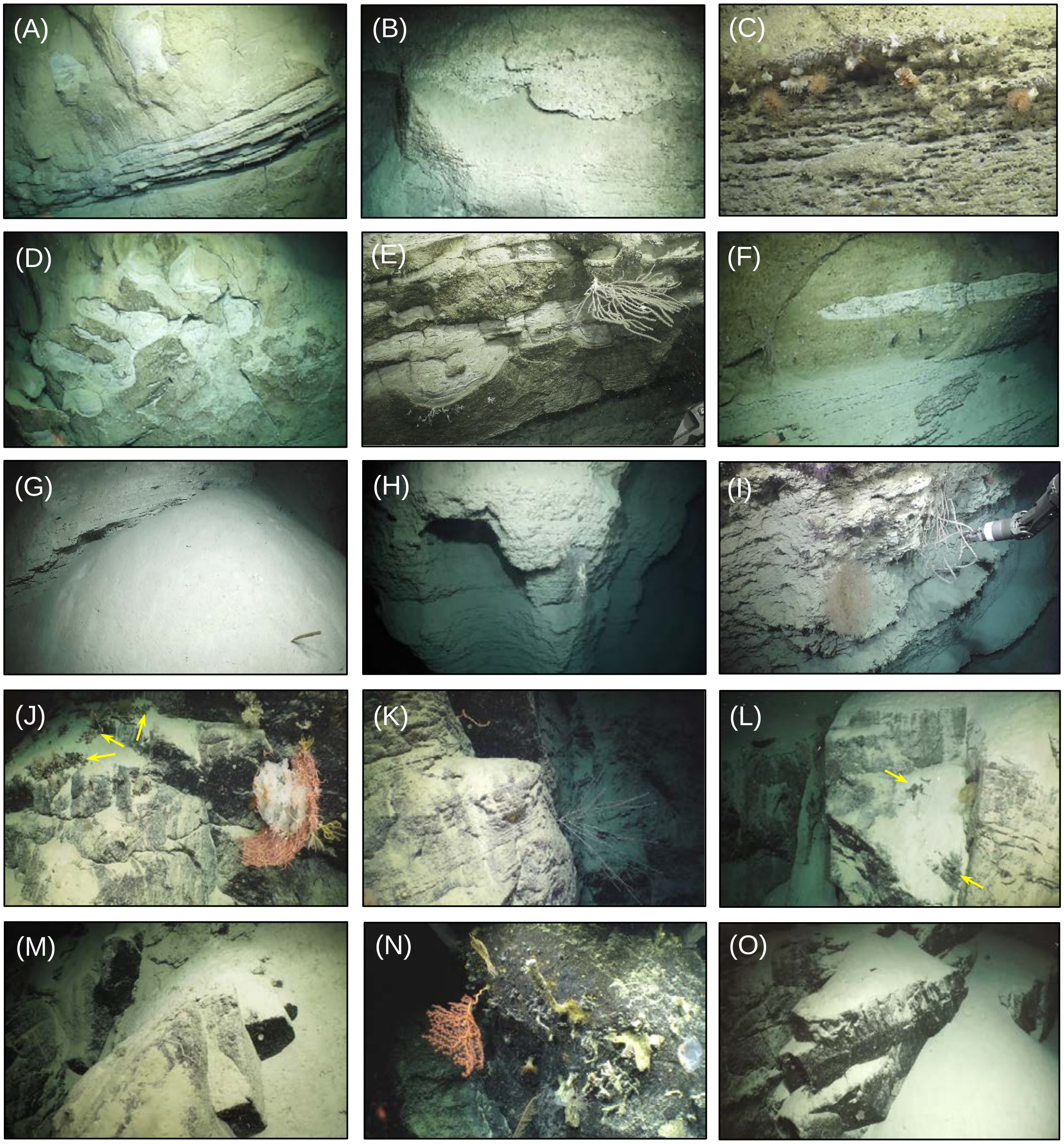
Pearson, P.N., Olsson, R.K., Huber, B.T., Hemleben, C., Berggren, W.A., (eds.), 2006. Atlas of Eocene planktonic foraminifera. Cushman Foundation for Foraminiferal Research, Special Publication 41, 513 pp.

van Morkhoven, P.C.M., Berggren, W.A., Edwards, A.S., 1986. Cenozoic cosmopolitan deep-water benthic foraminifera. Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, Memoir 11, 1–421.

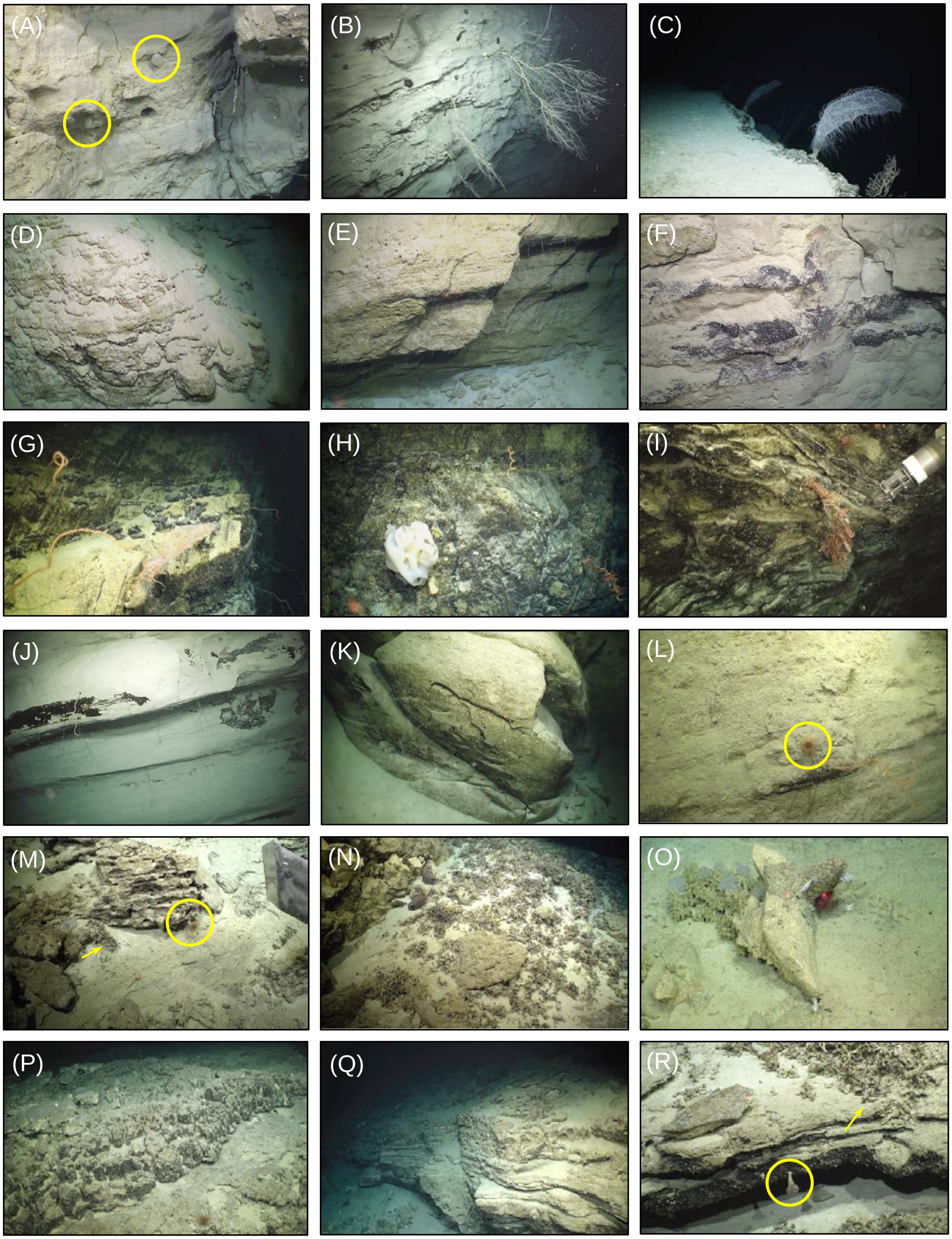
Wade, B.S., Olsson, R.K., Pearson, P.N., Huber, B.T., Berggren, W.A., (eds.), 2018. Atlas of Oligocene planktonic foraminifera. Cushman Foundation for Foraminiferal Research, Special Publication 46, 528 pp.

2 Supplementary Figures and Tables

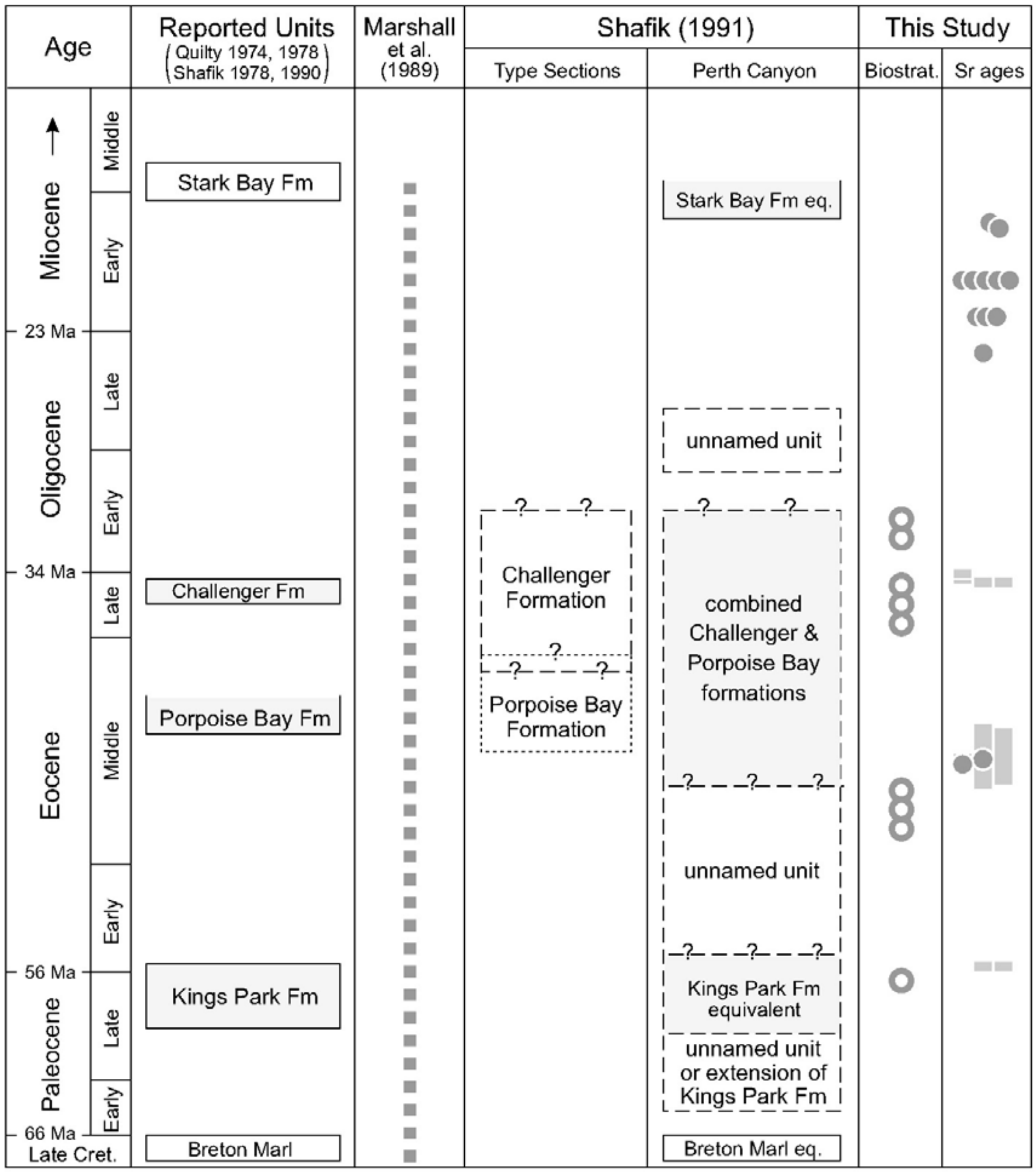
2.1 Supplementary Figures



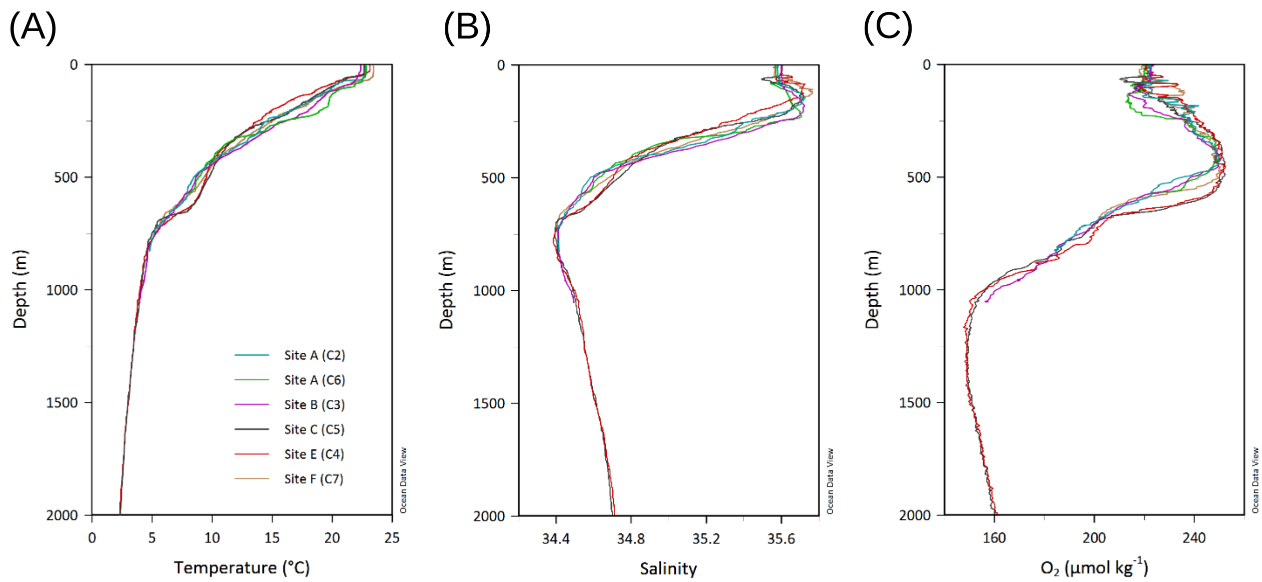
Supplement Figure 1. Representative images of the substrate and lithologies of the Perth Canyon for ROV dive Site A (A-F), Site B (G-I), and Site C (J-O). Note fossil debris (arrows).



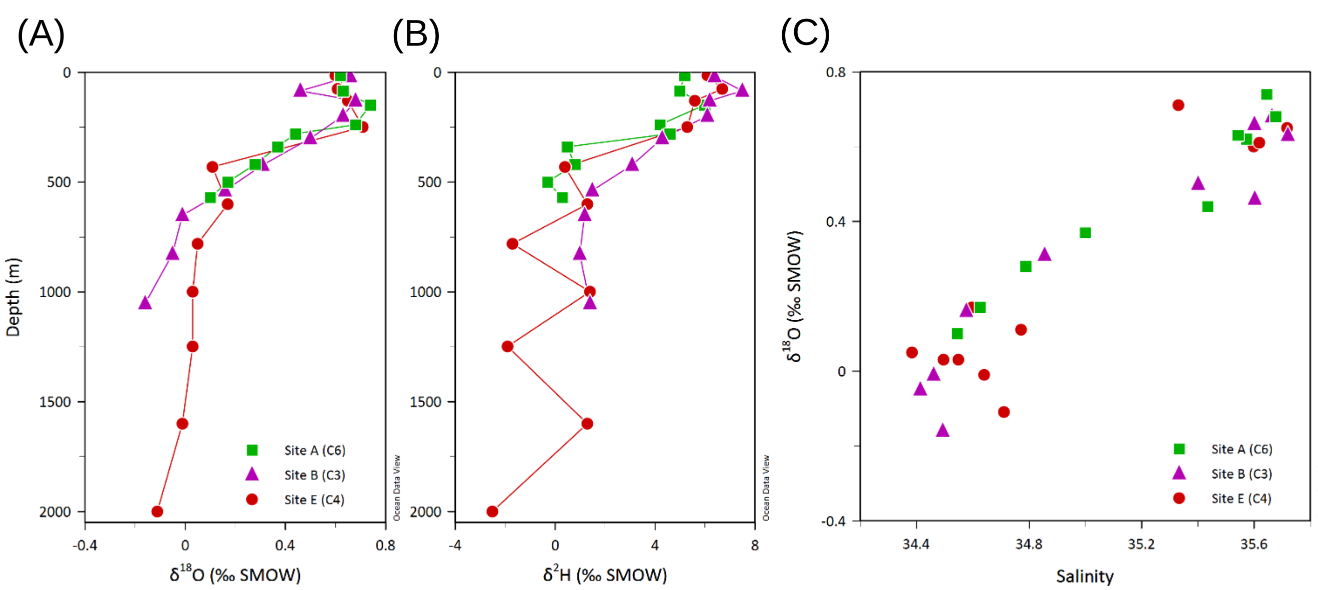
Supplement Figure 2. Representative images of the substrate and lithologies of the Perth Canyon for ROV dive Site D Glass Sponge Ridge (A-F), Site E Amphitheatre Waterfall (G-L), Site F (M-R). Circles highlight brachiopods (A) and cup corals (L, M, R), arrows indicate fossil debris (M, R). Note extensive fossil debris covering substrate (N).



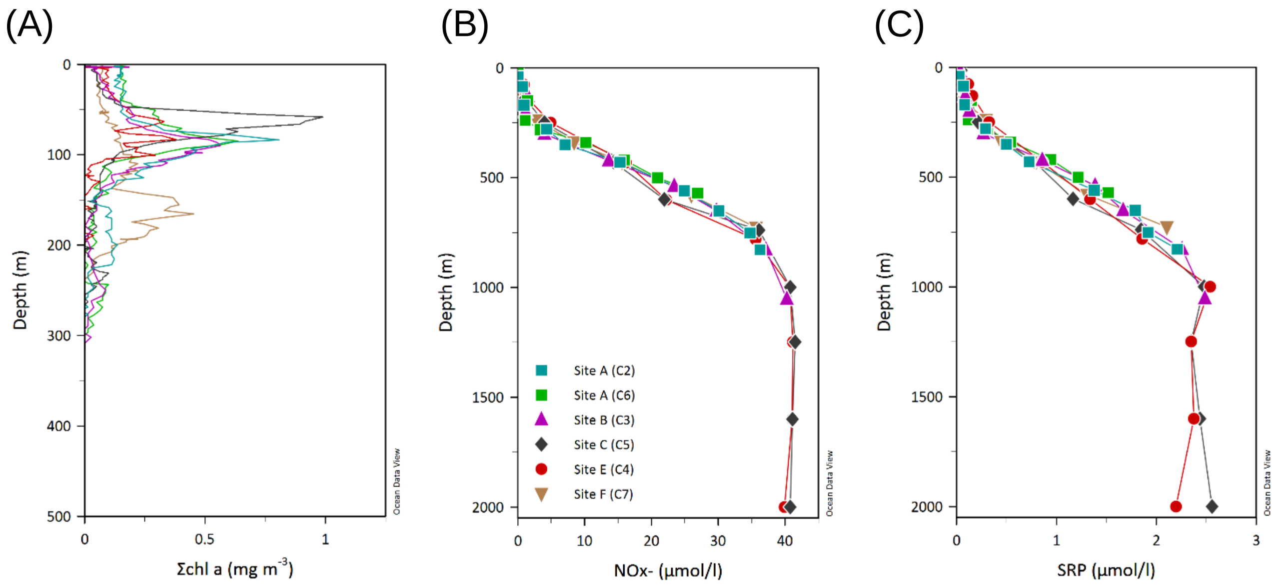
Supplement Figure 3. Regional stratigraphy and age ranges determined from geological samples from the Perth Canyon reported in prior studies (modified from Shafik, 1991) and from the present study. Dashed line illustrates range of biostratigraphic ages from Marshall et al., 1989. Open circles denote approximate ages determined from foraminifers, solid circles and bars indicate Sr isotope age ranges of samples collected during the *RV Falkor* cruise.



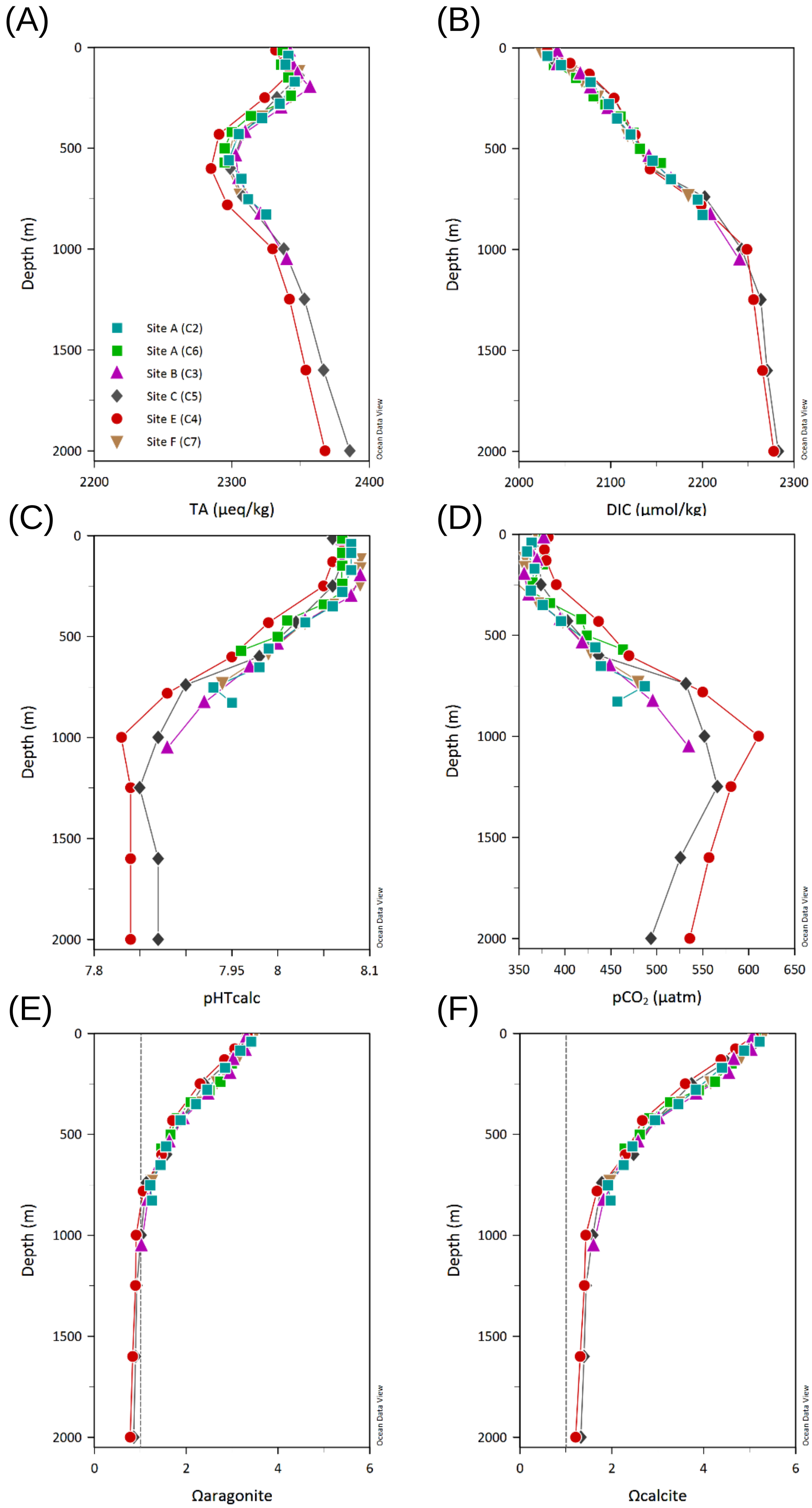
Supplementary Figure 4. Vertical profiles of temperature (A), salinity (B), and dissolved oxygen (C) recorded by the CTD at five ROV dive sites.



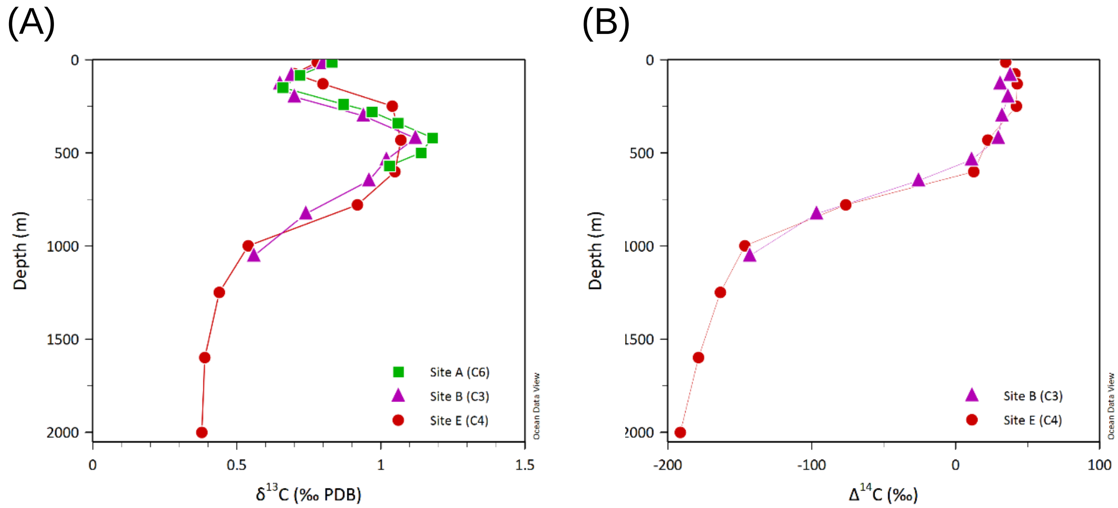
Supplementary Figure 5. Vertical profiles of seawater stable isotope compositions of oxygen (A) and hydrogen (B) at three of the ROV dive sites (Site A: Glider Crash, Site B: Derwent Wreck, Site E: Amphitheatre Waterfall). Seawater $\delta^{18}O$ isotope versus salinity plot (C).



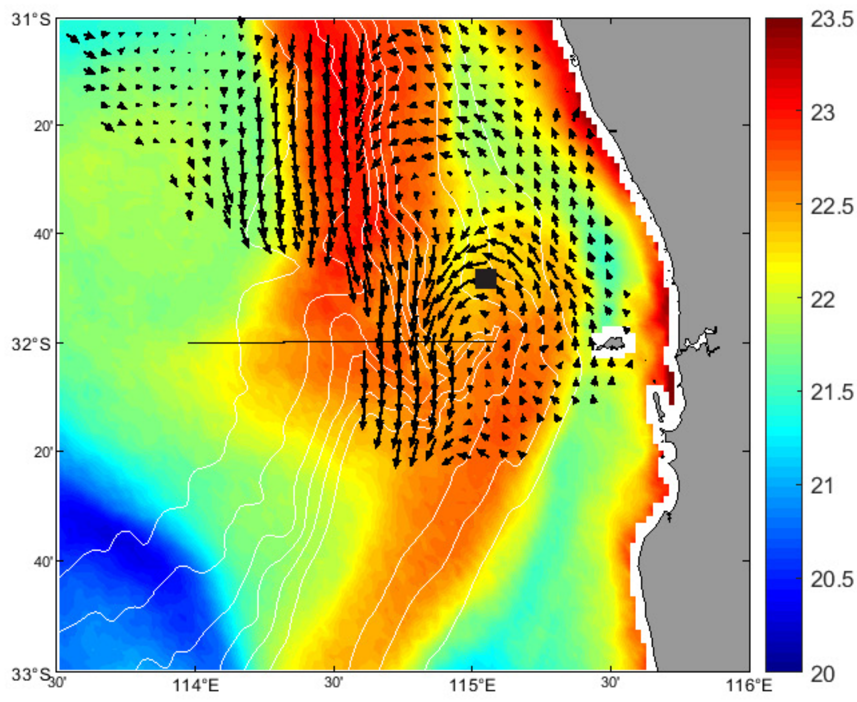
Supplementary Figure 6. Vertical profiles of chlorophyll *a* (A), dissolved nitrate plus nitrite (B), and soluble reactive phosphorus (C) at five ROV dive sites in the Perth Canyon. Note: 95% of all nutrient samples had ammonium concentrations less than 0.5 µM; shorter vertical scale (shallower depth range) on the chlorophyll plot.



Supplement Figure 7. Vertical profiles of seawater compositions for total alkalinity (A), dissolved inorganic carbon (B), calculated pH on the Total Scale (C), partial pressure of carbon dioxide (D), and carbonate saturation state for aragonite (E) and calcite (F) measured at five ROV dive sites.



Supplement Figure 8. Vertical profiles of seawater carbon isotope compositions, $\delta^{13}C$ (A) and $\Delta^{14}C$ (B) from the Perth Canyon (Site A: Glider Crash, Site B: Derwent Wreck, Site E: Amphitheatre Waterfall).



Supplement Figure 9. Surface currents measured by HF Radar systems (as arrows) overlain on satellite derived sea surface temperature map of the study region obtained on 9 March 2015. The colder water represents the northward flowing Capes Current whilst the warm water represent the Leeuwin Current. An eddy is located in the vicinity of the Perth Canyon. Black square represents the location of mooring at 500 m and the solid black line is the ocean glider transect.

References to Suppl. Fig. 3

Marshall, J.F., Ramsay, D. C., Lavering, I., Swift, M.G., Shafik, S., Graham, T.G. et al. (1989). Hydrocarbon prospectivity of the offshore South Perth Basin. BMR Records, 1989/23.

Shafik, S. (1978). Paleocene and Eocene nannofossils from the Kings Park Formation, Perth Basin, Western Australia. In Belford, DJ. & Scheibnerova, V. (compilers), The Crespin Volume: Essays in honour of Irene Crespin. Bureau of Mineral Resources, Australia, Bulletin 192, 165-171.

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2.2 Supplementary Tables

Supplementary Table 1. Sites and depths of seawater sampling collected from CTD-Rosette casts.

Depth	**Site A** **Glider Crash**	**Site A** **Glider Crash (#2)**	**Site B** **Derwent Wreck**	**Site C** **Dog-Leg Canyon**	**Site E** **Amphitheatre Waterfall**	**Site F** **Two Rocks**
water sample depth (m)	40	15	20	15	15	16
water sample depth (m)	85	85	85	60	77	115
water sample depth (m)	171	150	130	141	130	161
water sample depth (m)	280	240	200	250	251	240
water sample depth (m)	351	281	302	431	432	340
water sample depth (m)	430	340	423	600	602	431
water sample depth (m)	560	420	539	740	781	581
water sample depth (m)	651	501	651	1000	1000	728
water sample depth (m)	753	570	829	1250	1250	
water sample depth (m)	828		1053	1600	1600	
water sample depth (m)				2000	2000	
Total number of samples	10	9	10	11	11	8

Supplementary Table 2. Rock ages based on foram biostratigraphy and $^{87}Sr/^{86}Sr$ compositions.

Site	Depth (m)	Sample	Description	Biostrat. Age	Zone	Age Range (Ma)	$^{87}Sr/^{86}Sr$	Sr Age (Ma)	Sr Age min	Sr Age max	Epoch/Stage
Glider Crash (Site A):											
1	675	D8-S5_rk1-Cary	sediments from live *Caryophyllia* holdfast				0.708670	17.6	17.5	17.7	E. Mioc./Burd.
2	701	D8-S3	rock handsample for biostratgraphy	E. Olig.	O1-2	31-33					
3	701	D8-S3_rk1-Pol	sediments from live *Polymyces* holdfast				0.708443	20.9	20.9	21.0	E. Mioc./Aquit.
4	701	D8-S3_rk2-M	rock, mudstone nodule				0.708324	22.4	22.3	22.5	E. Mioc./Aquit.
		D8-S3_rk2-M (r)	(as above)				0.708327	22.4	22.3	22.5	E. Mioc./Aquit.
5	701	D8-S3_rk3-S	rock, siltstone nodule				0.708245	23.9	23.7	24.0	L. Olig./Chatt.
Two Rocks (Site F):											
6	717	D9-S4	rock handsample for biostratgraphy	E. Olig.	O1-2	31-33					
7	717	D9-S4_rk1-H	"pre-hardground"				0.708445	20.5	20.3	20.7	E. Mioc./Aquit.
8	717	D9-S4_rk2-M	mudstone nodule				0.708354	22.0	21.9	22.1	E. Mioc./Aquit.
		D9-S4_rk2-M (r)	(as above)				0.708357	21.9	21.8	22.0	E. Mioc./Aquit.
9	739	D9-S2	rock handsample for biostratgraphy	E. Olig.	O1-2	31-33					
10	746	D9-S2_rk1-Pol	sediments from live *Polymyces* holdfast				0.708690	17.4	17.3	17.5	E. Mioc./Burd.
		D9-S2_rk1-Pol (r)	(as above)				0.708695	17.0	16.9	17.2	E. Mioc./Burd.
11	746	D9-S1	rock handsample for biostratgraphy	E. Olig.	O1-2	31-33					
12	746	D9-S1_rk2	mudstone				0.708376	21.7	21.6	21.8	E. Mioc./Aquit.
Derwent Wreck (Site B):											
13	936	D4-S1_rk1-Des	sediments from live *Desmophyllum* holdfast				0.708485	20.1	20.0	20.2	E. Mioc./Burd.
14	936	D4-S1_rk2-Sol	sediments from fossil *Solenosmilia* holdfast				0.708499	19.9	19.8	20.0	E. Mioc./Burd.
15	936	D4-S1_rk3-Des	sediments from fossil *Desmophyllum* holdfast				0.708517	19.6	19.5	19.7	E. Mioc./Burd.

Supplementary Table 2 continued:

Site	Depth (m)	Sample	Description	Biostrat. Age	Zone	Age Range (Ma)	$^{87}Sr/^{86}Sr$	Sr Age (Ma)	Sr Age min	Sr Age max	Epoch/Stage
Glass Sponge Ridge (Site D):											
16	1032	D7-S5	rock handsample for biostratgraphy	M. Eoc.	E8-E12	34-40					
	1032	D7-S5_rk1-W	wackestone				0.707816[1]	34.7	34.4	35.2	L. Eoc./Priab.
									43.9	45.1	M. Eoc./Lute.
		D7-S5_rk1-W (r)	(as above)				0.707830	34.3	34.1	34.5	L. Eoc./Priab.
Amphitheatre Waterfall (Site E):											
17	1241	D5-S8	rock handsample for biostratgraphy	M. Eoc.	E10-E12	40-44					
18	1357	D5-S4_rk1	rock, small loose mudstone? fragments				0.707825[1]	35.1	34.7	35.8	L. Eoc./Priab.
									42.5	46.0	M. Eoc./Lute.
									55.6		E. Eoc./Ypres.
19	1472	D5-S3_rk1	sediments from *Vaughanella* holdfast				0.707826[1]	35.0	34.7	35.7	L. Eoc./Priab.
									42.7	45.9	M. Eoc./Lute.
									55.6		E. Eoc./Ypres.
20	1602	D5-S1_rk1	rock handsample for biostratgraphy	L. Paleoc.	P4c	56-56.5					

[1]ratios with multiple possible Sr ages; (r) = repeat

Supplementary Table 3. Radiocarbon analysis of seawater samples collected from Perth Canyon by Rosette casts at Sites B and E.

#	Location	Depth (m)	Sample ID	Lab ID	pMC		$\Delta^{14}C$ (‰)	
					Mean	Error (1σ)	Mean	Error (1σ)
1	Site B: Derwent Wreck	85	C3-B17	OZU207	104.64	0.33	38.1	3.3
2	Site B: Derwent Wreck	130	C3-B15	OZU206	103.93	0.29	31.0	2.9
3	Site B: Derwent Wreck	200	C3-B13	OZU205	104.47	0.30	36.4	3.0
4	Site B: Derwent Wreck	302	C3-B12	OZU204	104.07	0.28	32.4	2.8
5	Site B: Derwent Wreck	423	C3-B9	OZU203	103.81	0.31	29.8	3.1
6	Site B: Derwent Wreck	539	C3-B7	OZU202	101.94	0.28	11.3	2.8
7	Site B: Derwent Wreck	651	C3-B5	OZU201	98.22	0.27	-25.6	2.7
8	Site B: Derwent Wreck	829	C3-B3	OZU200	91.06	0.34	-96.6	3.4
9	Site B: Derwent Wreck	1053	C3-B1	OZU199	86.41	0.27	-142.8	2.7
10	Site E: Amphitheatre Waterfall	15	C4-B20	OZU218	104.33	0.33	35.0	3.3
11	Site E: Amphitheatre Waterfall	77	C4-B16	OZU217	104.96	0.33	41.3	3.3
12	Site E: Amphitheatre Waterfall	130	C4-B15	OZU216	105.13	0.32	42.9	3.2
13	Site E: Amphitheatre Waterfall	251	C4-B14	OZU215	105.07	0.69	42.3	6.8
14	Site E: Amphitheatre Waterfall	432	C4-B12	OZU214	103.07	0.29	22.5	2.9
15	Site E: Amphitheatre Waterfall	602	C4-B10	OZU213	102.08	0.30	12.7	3.0
16	Site E: Amphitheatre Waterfall	781	C4-B8	OZU212	93.13	0.31	-76.1	3.1
17	Site E: Amphitheatre Waterfall	1000	C4-B7	OZU211	86.05	0.27	-146.3	2.7
18	Site E: Amphitheatre Waterfall	1250	C4-B5	OZU210	84.35	0.25	-163.2	2.5
19	Site E: Amphitheatre Waterfall	1600	C4-B3	OZU209	82.81	0.28	-178.5	2.8
20	Site E: Amphitheatre Waterfall	2000	C4-B1	OZU208	81.53	0.26	-191.2	2.6

Supplementary Table 4. Uranium-series analyses of fossil deep-water coral skeletons.

Site	Sample name	Depth m	Water Mass	^{230}Th nmol/g	^{232}Th nmol/g	^{238}U nmol/g	[^{230}Th/^{238}U]	±2SE	[^{230}Th/^{232}Th]	$\delta^{234}U_m$	±2SE	$\delta^{234}U_i$	± 2SE	Age (ka)	Age$_c$ (ka BP)
Dog-Leg Canyon (Site C):															
1	FPC15_D06-S7_Des1F	1558	UCDW	0.00007	0.0171	18.0	0.224	0.0003	743	131.1	0.4	140.2	0.5	23.998	23.872
2	FPC15_D06-S7_Des2F	1558	UCDW	0.00005	0.0139	14.8	0.217	0.0003	725	138.2	0.4	147.4	0.5	23.010	22.885
3	FPC15_D06-S7_Des4F	1558	UCDW	0.00005	0.0066	16.9	0.172	0.0001	1387	139.3	0.5	146.5	0.5	17.793	17.699
4	FPC15_D06-S3_Des1F	1788	UCDW	0.00006	0.0117	14.6	0.245	0.0004	957	131.3	0.4	141.5	0.4	26.447	26.331
5	FPC15_D06-S3_Des2F	1788	UCDW	0.00007	0.0141	18.4	0.231	0.0003	946	131.3	0.4	140.8	0.4	24.797	24.683
6	FPC15_D06-S3_Des3F	1788	UCDW	0.00008	0.0012	17.2	0.270	0.0003	11861	127.3	0.4	138.4	0.5	29.738	29.665
7	FPC15_D06-S3_Des4F	1788	UCDW	0.00007	0.0058	23.6	0.183	0.0001	2323	135.5	0.5	143.0	0.5	19.140	19.055
8	FPC15_D06-S3_Des5F	1788	UCDW	0.00005	0.0123	11.2	0.271	0.0002	778	133.6	0.5	145.2	0.5	29.593	29.456
9	FPC15_D06-S3_Des6F	1788	UCDW	0.00009	0.0051	17.9	0.296	0.0002	3263	128.4	0.5	140.9	0.5	32.982	32.894
Two Rocks (Site F):															
10	FPC15_D09-S5_Sol1F-1	691	AAIW	0.00005	0.0005	13.8	0.232	0.0006	21526	130.1	0.4	139.6	0.4	24.951	24.882
	FPC15_D09-S5_Sol1F-2 (r)	691	AAIW	0.00005	0.0005	13.5	0.232	0.0004	20740	129.7	0.4	139.2	0.4	24.980	24.911
11	FPC15_D09-S5_Sol2F-1	691	AAIW	0.00006	0.0004	15.1	0.232	0.0004	24751	129.9	0.4	139.3	0.4	24.909	24.840
	FPC15_D09-S5_Sol2F-2 (r)	691	AAIW	0.00006	0.0004	14.2	0.232	0.0004	25890	129.8	0.4	139.3	0.4	25.005	24.936
12	FPC15_D09-S5_Sol3F-1	691	AAIW	0.00006	0.0005	15.0	0.233	0.0004	21791	129.8	0.4	139.4	0.4	25.123	25.054
13	FPC15_D09-S4_Sol2F-1	691	AAIW	0.00006	0.0029	17.3	0.216	0.0005	4040	131.9	0.4	140.7	0.4	23.016	22.939
	FPC15_D09-S4_Sol2F-2 (r)	691	AAIW	0.00006	0.0023	15.5	0.216	0.0005	4511	131.4	0.4	140.2	0.4	22.961	22.885
14	FPC15_D09-S5_Des1F	691	AAIW	0.00006	0.0106	17.6	0.214	0.0004	1112	138.0	0.4	147.1	0.4	22.598	22.495
15	FPC15_D09-S5_Des2F	691	AAIW	0.00006	0.0061	15.6	0.235	0.0003	1887	131.5	0.4	141.2	0.4	25.278	25.187
16	FPC15_D09-S5_Des3F	691	AAIW	0.00006	0.0026	15.9	0.215	0.0001	4070	146.6	0.5	156.2	0.5	22.546	22.466
17	FPC15_D09-S5_Des4F	691	AAIW	0.00006	0.0035	15.3	0.217	0.0002	2999	135.6	0.5	144.7	0.5	23.072	22.988
18	FPC15_D09-S5_Des5F	691	AAIW	0.00006	0.0035	16.2	0.215	0.0002	3091	136.1	0.2	145.1	0.2	22.747	22.664
19	FPC15_D09-S5_Sol4F	691	AAIW	0.00007	0.0035	18.6	0.238	0.0002	3987	129.5	0.2	139.2	0.2	25.676	25.595
20	FPC15_D09-S5_Sol5F	691	AAIW	0.00007	0.0027	17.5	0.237	0.0002	4764	130.7	0.3	140.5	0.4	25.505	25.426

Supplementary Table 4 continued:

Site	Sample name	Depth m	Water Mass	^{230}Th nmol/g	^{232}Th nmol/g	^{238}U nmol/g	[^{230}Th/^{238}U]	± 2SE	[^{230}Th/^{232}Th]	$\delta^{234}U_m$	± 2SE	$\delta^{234}U_i$	± 2SE	Age (ka)	Age$_C$ (ka BP)
21	FPC15_D09-S4_Sol1F	717	AAIW	0.00006	0.0018	15.1	0.222	0.0003	5939	136.6	0.4	146.0	0.5	23.565	23.490
22	FPC15_D09-S4_Des1F	717	AAIW	0.00007	0.0037	17.3	0.223	0.0003	3310	130.6	0.4	139.7	0.5	23.850	23.769
23	FPC15_D09-S4_Des2F	717	AAIW	0.00007	0.0102	19.7	0.221	0.0002	1345	132.8	0.3	141.9	0.4	23.567	23.468
24	FPC15_D09-S4_Des3F	717	AAIW	0.00007	0.0014	18.1	0.212	0.0002	8660	144.3	0.3	153.6	0.4	22.305	22.232
25	FPC15_D09-S4_Des4F	717	AAIW	0.00006	0.0014	16.4	0.213	0.0002	8079	146.4	0.5	155.9	0.5	22.295	22.220
26	FPC15_D09-S4_Des5F	717	AAIW	0.00006	0.0048	15.5	0.221	0.0002	2258	140.5	0.5	150.1	0.5	23.372	23.283
27	FPC15_D09-S4_Des7F	717	AAIW	0.00006	0.0101	16.1	0.224	0.0002	1121	143.7	0.5	153.6	0.5	23.712	23.604
28	FPC15_D09-S4_Sol3F	717	AAIW	0.00007	0.0038	18.9	0.215	0.0001	3401	132.0	0.5	140.8	0.5	22.909	22.827
29	FPC15_D09-S4_Sol4F	717	AAIW	0.00006	0.0032	16.1	0.218	0.0002	3445	133.2	0.5	142.2	0.5	23.256	23.174
30	FPC15_D09-S1_Sol1F	746	AAIW	0.00008	0.0073	18.2	0.250	0.0003	1959	133.1	0.4	143.7	0.5	27.091	26.999
31	FPC15_D09-S1_Sol2F	746	AAIW	0.00008	0.0025	20.1	0.232	0.0001	5975	134.3	0.5	144.1	0.5	24.880	24.803

Brackets denote activity ratios.
[^{230}Th/^{232}Th] ratios determined using a Th-U spike calibrated to reference material HU-1 assuming secular equilibrium.
δ^{234}U reported as measured (m) and corrected initial (i) values.
Age (ka) is calculated through iterative age estimation (Ludwig and Titterington, 1994), using the ^{230}Th, ^{234}U and ^{238}U decay constants of Cheng et al. (2013) and Jaffey et al. (1971).
Age$_C$ (ka BP) is the corrected age calculated with initial non-radiogenic [^{230}Th/^{232}Th] = 2 (±1) and reported as ka Before Present (BP), where Present is defined as the year 1950 C

References to Suppl. Table 4

Cheng, H., Edwards, R.L., Shen, C-C., Polyak, V.J., Asmerom, Y., Woodhead, J. et al. (2013). Improvements in ^{230}Th dating, ^{230}Th and ^{234}U half-life values, and U–Th isotopic measurements by multi-collector inductively coupled plasma mass spectrometry. Earth and Planetary Science Letters, 371–372, 82–91, 2013.

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