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Supplemental Material

Figure S1: Geologic map of Cape Range depicting the Neogene and Quaternary units described in the text. Map is modified from Steward et al. (2008) surficial geology map of Western Australia (1:1,000,000). All four terraces from this study are contained in the undifferentiated “Bundera Calcerenite” unit (and in the thin “Exmouth Sandstone” unit to the south). Dotted black line showing transects from Fig. 2A and 4A, and blue line depicts outline of the modern Ningaloo Reef.

Figure S2: Examples of scanning electron microscope (SEM) and optical imagery preservation on coral and oyster samples. (A-E) SEM images showing various stages of alteration. (F-H) Optical images of Faviidae corals and oyster shells (I-J) showing different levels of preservation. (Bottom left) Preservation score for each image. Notice extensive iron staining for optical samples with a preservation score of 3. A.—aragonite, C.—calcite.

Figure S3: (Left) Sr/Ca vs. Mn/Ca for coral samples from Cape Range. Muiron coral sample CR-FMW-1H displays the highest Mn/Ca value, followed by CR-TQS-Tp#2, and CR-LFYN-1A, indicating post-depositional alteration. Sr/Ca (to first degree) is thought to be a reflection of alteration from aragonite to calcite, therefore, samples with lower Sr/Ca ratios are generally more weathered/altered. The green box is the 2σ range of unaltered coral, and dashed boxes show multiples of that range. Cross-hatched sections are furthest from the range of pristine coral and thought to be the most altered. (Right) Sr/Ca vs. Mn/Ca for oyster samples from Cape Range. Notice high Mn/Ca ratios for sample CR-BJM-2C, indicating post-depositional diagenesis. General clustering of oyster samples show relatively low Mn/Ca. Modern standard (green point) is average of measurements of the Tridactna standard JCT-1 ($n=3$). Orange point shows well-preserved LIG/Holocene oyster. Red line is the maximum Mn/Ca range for modern coral (Shen et al. 1991).

Figure S4: Enlargement of lower elevation fossil shorelines from figure 4 in main text. Additional details include elevations of *in-situ* isolated patch reefs and coral heads (yellow circles), highest Tantabiddi marine sediment (red line), and Jurabi beach (yellow-black squares) and marine (teal diamond) sediments. Isolated corals all have a +2 m depth uncertainly marked (in blue), following modern indicative range of average lagoon depth and near shore coral, but could have lived deeper. However, the +2 m depth uncertainty for the Tantabiddi coral reef (orange circles) and Jurabi coral reef (blue circles) is thought to be a maximum based on indicative range of those features and other corresponding sea level markers.

Figure S5: Map of LIG coral reef terrace with locations and ages of open-system corrected U-Series ages from O’Leary et al. (2013). Orange points and text are elevations from this study.

Figure S6: Flow chart showing the steps and calculations for finding relative deformation rates and paleo RSL estimates used in this study.

Figure S7: Model of relative deformation at Cape Range through time. Calculated at each time slice by subtracting the elevation of the youngest terrace in each panel (blue sea level) from preceding terraces at each shore perpendicular transect. (A) Relative deformation of Muiron terrace at time of Milyering sea level. (B) Relative deformation of both Muiron and Milyering terraces at timing of Jurabi deposition (~1 Ma). (C) Relative deformation of older terraces at timing of upper Tantabiddi notch/scarp. While timing of that feature is highly uncertain, notice some deformation of Jurabi has occurred. (D) Current relative deformation of three upper shorelines and upper Tantabiddi notch, same as in figure 4b (main text).

Figure S8: Highest shoreline elevations plotted against SIS ages from the best preserved sample for each terrace (width of colored boxes represent age error). Based on leach trends these should generally be minimum ages. Dark blue line shows the transect through Turquoise Bay (TQS), near the anticline apex. The shaded purple region represents the range of elevations of each terrace in the southern limb, and shaded teal shows the northern limb, with its greater relative deformation. Notice increasing spread of highest shoreline features with age, recording the amount of relative deformation.

TABLE S1: MODERN INDICATIVE RANGE AND GPS CONFIRMATION OF MEAN SEA LEVEL

TABLE S2: ELEMENTAL ANALYSIS AND PRESERVATION SCORES

TABLE S3: UNALTERED CARBONATE UNCERTAINTIES - PRESERVATION SCORE

TABLE S4: STRONTIUM ISOTOPE STANDARDS NBS 987 AND MODERN CORAL

TABLE S5: STRONTIUM ISOTOPES BY AVERAGE LEACH

REFERENCE CITED

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113.5°E

113.8°E

114.0°E

N

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TABLE S1: MODERN INDICATIVE RANGE AND GPS CONFIRMATION OF MEAN SEA LEVEL

Indicative Range Type	Description	Average Elevation (msl)	Error 2 σ (SEM)	n	Indicative Range (m)	Max. elevation (m)	Min. elevation (m)
Tidal Notch*	Modern notch, near base, close to msl	-0.14	0.10	8	0.44	0.11	-0.33
Coral Heads - patch reef *	Coral heads growing near the tidal zone	-0.41	0.03	7	0.14	-0.37	-0.51
Modern Beach*	Beach deposits around Cape Range	0.66	0.44	12	2.17	1.80	-0.37
Abrasion Ramp*	Modern abrasion ramp	-0.33	0.04	8	0.18	-0.21	-0.39
Depth of Lagoon[†]	From Rovere et al. (2016) SM average	2.04	0.46	40	7.62	-0.38	-8.00
Edge of Forereef[†]	From Rovere et al. (2016) SM average	1.93	0.52	34	6.60	-0.40	-7.00
GPS Confirmation Type [§]	Description	Elevation (msl)	Error (2 σ)	n	Expected Elevation (msl)	Difference (m)	Within Error?
Modern Notch	Modern notch, near base, close to msl	-0.14	0.27	8	0 $\pm$ 0.15	-0.14	Yes
High Tide Mark	High tide mark on beach at LFY	1.09	0.17	1	1 $\pm$ 0.5	+0.09	Yes
Water Level Mark	Yardie Creek Water level - groundwater	-0.05	0.09	1	0 $\pm$ 0.5	-0.05	Yes

* Data from this study, measured around Cape Range

[†] Global data taken from Rovere et al. (2016), supplemental material

[§] dGPS measurements at modern SL features to confirm accuracy of Geoid AHD at Cape Range.

TABLE S2: ELEMENTAL ANALYSIS AND PRESERVATION SCORES

Sample Code	# Splits Measured	terrace	Na/Ca (mmol/mol)	Mg/Ca (mmol/mol)	Al/Ca (μmol/mol)	Mn/Ca (μmol/mol)	Fe/Ca (μmol/mol)	Sr/Ca (mmol/mol)	Ba/Ca (μmol/mol)	U/Ca (nmol/mol)	Elemental Preservation Score (1-3) [†]
Oyster Samples											
CR-LFY-2A *	1	Muiron	2.3	16.1	BDL	5.0	BDL	0.64	2.5	60	2.00
CR-BJM 2C	2	Milyering	0.1	14.4	4.9	21.5	34.0	0.64	3.8	72	2.67
CR-MGC-1B	3	Milyering	6.0	9.3	6.8	4.6	25.6	0.49	2.1	62	2.33
CR-MGC-2B *	2	Milyering	7.2	12.5	47.2	5.2	BDL	1.51	6.8	50	1.67
CR-PGMS-1A	2	Jurabi	8.4	16.4	2.0	5.5	1.7	0.97	2.4	58	2.00
CR-PSWN-2B	2	LIG	7.2	16.3	80.3	3.6	BDL	1.44	5.7	23	1.67
JCt-1 (tridactna)	3	Modern	19.9	1.2	17.2	2.6	BDL	1.84	1.6	33	1.00
Coral Samples											
CR-FMW-1H	1	Muiron	2.8	5.5	11.2	15.3	47.0	1.87	11.5	42	2.60
CR-LFYN-1A	1	Muiron	2.9	11.8	BDL	5.2	23.0	1.91	11.2	58	2.60
CR-TQS-Tp #1	1	Muiron	2.9	15.6	17.3	2.3	3.2	1.91	11.2	47	2.00
CR-TQS-Tp #2	2	Muiron	2.8	11.1	10.1	7.3	BDL	1.88	11.0	44	2.20
CR-MDU-1A	3	Jurabi	4.3	12.1	0.8	3.4	4.5	3.61	12.0	352	1.80
CR-MDU-1B	1	Jurabi	3.7	22.5	1.6	3.3	3.1	1.87	15.1	326	2.20
CR-MDU-3C *	2	Jurabi	3.4	10.2	BDL	2.9	BDL	4.49	3.4	749	1.60
CR-TQSS-1A	2	Jurabi	3.7	18.6	0.6	2.4	26.5	3.90	13.6	416	2.40
XZB-31-1b-A	1	Jurabi	3.4	7.3	230.6	4.9	382.1	3.12	12.5	527	2.40
XZB-31-1b-B	2	Jurabi	3.5	8.4	1038.4	4.0	776.8	2.98	13.8	480	2.40
CR-BJM 2A.1	2	LIG	16.8	3.8	16.6	2.1	BDL	7.72	4.8	1112	1.00
CR-CGIN-1A.1	2	LIG	16.6	4.5	47.5	3.0	93.8	8.12	5.4	1199	1.40
CR-CGIN-1B.1	2	LIG	17.8	3.8	24.3	3.5	BDL	7.62	15.6	1108	1.00
CR-OPYS-1B.A	1	LIG	18.8	3.6	BDL	3.3	BDL	7.54	5.3	1000	1.00
CR-TKBN-1A.1	2	LIG	17.9	4.0	35.0	3.5	3.1	7.63	6.2	1211	1.00
CR-BRK-2A.S1	1	Holocene	20.4	4.1	BDL	3.5	BDL	7.64	5.1	1248	1.00
CR-PSWN-1D	2	Holocene	17.6	3.1	9.7	2.6	BDL	9.33	4.6	1196	1.00
JCp-1	6	Modern	19.7	4.2	55.7	3.3	3.7	8.22	4.0	1181	1.00
V03 Standard	≤ 86	(% error 2σ)	1.34%	1.30%	15.90%	1.20%	2.10%	1.40%	1.80%	3.00%	

Preservation Score [§]		
Well Preserved	1	Within 2σ (unaltered)
Some Alteration	2	2σ ± range of 2σ (alteration evident)
Highly Altered	3	Outside 2σ ± range (major alteration)
Not scored		Not included in preservation score

*Best preserved samples chosen for terrace SIS age constraints

[†] Total preservation score is calculated by averaging the colored boxes for each sample[§] Preservation score is calculated based on unaltered Holocene samples, see Table DR3

TABLE S3: UNALTERED CARBONATE UNCERTAINTIES - PRESERVATION SCORE

Holocene Coral and Bivalves	<u>Bivalves and Coral (n = 22)</u>					<u>Coral Only (n=17)</u>		
	Na/Ca (mmol/mol)	Mg/Ca (mmol/mol)	Al/Ca (μ mol/mol)	Mn/Ca (μ mol/mol)	Fe/Ca (μ mol/mol)	Sr/Ca (mmol/mol)	Ba/Ca (μ mol/mol)	U/Ca (nmol/mol)
Average	21.66	3.98	25.22	2.76	2.82	7.83	6.44	1120.95
2 σ	5.37	3.95	41.24	1.72	6.50	1.48	8.10	161.00
Range	10.73	7.89	82.47	3.44	13.01	2.97	16.20	321.99
Count	22	22	22	22	20	15	17	17
MAX (2 σ) *	27.03	7.93	66.45	4.48	9.32	9.32	14.53	1281.94
MIN (2 σ)	16.29	0.04	0.00	1.04	0.00	6.35	0.00	959.95
MAX 2 σ + RANGE [†]	37.76	15.82	148.92	7.92	22.33	12.28	30.73	1603.94
MIN 2 σ + RANGE	5.56	0.00	0.00	0.00	0.00	3.38	0.00	637.96
> 2 σ + RANGE [§]	> 37.76	> 15.82	> 148.92	> 7.92	> 22.33	> 12.28	> 30.73	> 1603.94
< 2 σ + RANGE	< 5.56	< 0.00	< 0.00	< 0.00	< 0.00	< 3.38	< 0.00	< 637.96

* Preservation score of "1" if within max and min of 2 σ

[†] Preservation score of "2" if within max and min of 2 σ + range

[§] Preservation score of "3" if over max/min of 2 σ + range

TABLE S4: STRONTIUM ISOTOPE STANDARDS NBS 987 AND MODERN CORAL

Season Calculated	Avg. ⁸⁷ Sr/ ⁸⁶ Sr (no 2σ outliers)	2σ Uncertainty	n (filaments)	ppm error	Offset from Accepted Value*	Within Uncertainty [†]	
NBS 987 Standard							
FALL 2015	0.7102489	0.0000113	51	15.9	-0.0000009	Yes	
FALL 2016	0.7102445	0.0000079	40	11.1	0.0000035	Yes	
FALL 2018	0.7102414	0.0000072	27	10.1	0.0000066	Yes	
SPRING 2018	0.7102412	0.0000075	78	10.5	0.0000068	Yes	
SUMMER 2019	0.7102431	0.0000093	21	13.0	0.0000049	Yes	
AVERAGE (4 yr)	0.7102434	0.0000102	220	14.3	0.0000046	Yes	
Season Calculated	⁸⁷ Sr/ ⁸⁶ Sr (measured)	2σ Uncertainty	n (filaments)	ppm error	Correction factor (NBS 987 Offset)	⁸⁷ Sr/ ⁸⁶ Sr (NBS normalized)	Within Uncertainty [§]
Modern Carbonate Standards							
FALL 2016	0.7091685	0.0000086	18	12.20	0.0000035	0.7091720	Yes
FALL 2018	0.7091647	0.0000062	8	8.69	0.0000066	0.7091714	Yes

* Offset is based on subtracting average Sr isotope from accepted NBS 987 value of 0.710248

[†] Yes = 2σ uncertainty within accepted value of NBS 987 (0.710248 ± 0.000023) based on Thirlwall, 1991 (n=427).

[§] Same as above, but within accepted value of modern seawater $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.7091749 ± 0.0000010 (LOWESS 5, McArthur et al., 2012)

TABLE S5: STRONTIUM ISOTOPES BY AVERAGE LEACH

Sample ID (with leach #)	n [†]	Avg. ⁸⁷ Sr/ ⁸⁶ Sr (normalized) [#]	External Std. error (2σ)	Mean SIS age (Ma)	Max SIS Age (Ma) [§]	Min SIS Age (Ma) [§]	older error (Ma)	younger error (Ma)
<u>Jurabi terrace</u>								
CR-MDU-1A L1	1	0.7091519	0.0000075	0.690	0.860	0.485	0.170	0.205
CR-MDU-1A L4	3	0.7091529	0.0000061 [§]	0.665	0.810	0.500	0.145	0.165
CR-MDU-1A L5	1	0.7091595	0.0000079	0.480	0.695	0.250	0.215	0.230
CR-MDU-1B L1	1	0.7092105	0.0000113	Above SW	Above SW	Above SW	N.D.	N.D.
CR-MDU-1B L3	2	0.7091959	0.0000113	Above SW	Above SW	Above SW	N.D.	N.D.
CR-MDU-1B L4	1	0.7091940	0.0000079	Above SW	Above SW	Above SW	N.D.	N.D.
CR-MDU-3C L1	2	0.7091354	0.0000102	1.035	1.205	0.835	0.170	0.200
CR-MDU-3C L5 *	6	0.7091310	0.0000037 [§]	1.110	1.170	1.045	0.060	0.065
CR-PGMS-1A L1	1	0.7091929	0.0000075	Above SW	Above SW	Above SW	N.D.	N.D.
CR-PGMS-1A L2	1	0.7091829	0.0000075	Above SW	Above SW	Above SW	N.D.	N.D.
CR-PGMS-1A L3	1	0.7091813	0.0000075	Above SW	0.095	Above SW	0.095	N.D.
CR-PGMS-1A L4	1	0.7091673	0.0000075	0.250	0.470	0.005	0.220	0.245
CR-PGMS-1A Matrix FD	1	0.7093509	0.0000075	Above SW	Above SW	Above SW	N.D.	N.D.
CR-TQSS-1A #1 L1	1	0.7091553	0.0000113	0.600	0.870	0.270	0.270	0.330
CR-TQSS-1A #1 L3	4	0.7091499	0.0000044 [§]	0.735	0.840	0.625	0.105	0.110
CR-TQSS-1A #1 L4	2	0.7091462	0.0000079	0.820	0.980	0.630	0.160	0.190
CR-TQSS-1A #1 L5	1	0.7091339	0.0000123	1.060	1.260	0.820	0.200	0.240
<u>Milvering terrace</u>								
CR-BJM-2C L4	1	0.7090977	0.0000075	1.705	1.860	1.560	0.155	0.145
CR-MGC-1B Drill FD	5	0.7091032	0.0000210 [§]	1.595	2.060	1.220	0.465	0.375
CR-MGC-1B frag L2	1	0.7090813	0.0000061	2.080	2.285	1.925	0.205	0.155
CR-MGC-1B frag L4	1	0.7090768	0.0000079	2.230	2.570	1.995	0.340	0.235
CR-MGC-2B FD	3	0.7090548	0.0000039 [§]	3.795	4.265	3.355	0.470	0.440
CR-MGC-2B L1	1	0.7090617	0.0000079	3.050	3.915	2.525	0.865	0.525
CR-MGC-2B L4 *	4	0.7090668	0.0000041 [§]	2.685	2.975	2.470	0.290	0.215
<u>Muiron terrace</u>								
CR-FWH-1H L4	2	0.7097828	0.0000079	Above SW	Above SW	Above SW	N.D.	N.D.
CR-LFY-2A FD	1	0.7089690	0.0000075	6.460	6.655	6.285	0.195	0.175
CR-LFY-2A L1	1	0.7089593	0.0000082	6.725	6.990	6.500	0.265	0.225
CR-LFY-2A L4 *	2	0.7089658	0.0000073	6.540	6.750	6.360	0.210	0.180
CR-LFYN-1A L1	1	0.7091689	0.0000113	0.220	0.540	0.000	0.320	0.220
CR-LFYN-1A L3	1	0.7091730	0.0000113	0.120	0.410	0.000	0.290	0.120
CR-LFYN-1A L4	1	0.7091619	0.0000079	0.405	0.635	0.195	0.230	0.210
CR-TQS Tp#1 L4	1	0.7088788	0.0000079	10.190	10.485	9.930	0.295	0.260
CR-TQS-Tp#2 L1	1	0.7088605	0.0000075	10.890	11.205	10.600	0.315	0.290
CR-TQS Tp#2 L4	2	0.7088562	0.0000079	11.070	11.420	10.745	0.350	0.325

* Sample leaches included in final terrace age calculations

† Number of filaments measured and used in leach average

§ Errors calculated using 2σ standard error of the mean for sample filaments

Unknowns are normalized to NBS SRM 987 ⁸⁷Sr/⁸⁶Sr values of 0.710248 for comparison with the SIS curve (McArthur et al., 2012)Above SW = Above modern seawater ⁸⁷Sr/⁸⁶Sr values of 0.7091749 (McArthur et al., 2012)

N.D. = not determined