Climate instability during the Last Interglacial: Abrupt sea level events

William G Thompson[a] and H. Allen Curran[b]
[a]Woods Hole Oceanographic Institution
[b]Smith College

Abrupt sea-level events

The coral record of sea level for the Last Interglacial has been extensively studied and there is a widely held consensus that the sea-level highstand at this time was exceptionally long and stable (e. g. (1)). Recently, this view was challenged by a new sea-level record developed using published coral data and a new age-calculation method designed to overcome well-known problems with U/Th coral dating (2). In order to better understand the details of Last Interglacial sea-level change, we have undertaken a detailed stratigraphic study of Last Interglacial coral deposits worldwide. Here we report results from more than 200 new coral ages from San Salvador and Great Inagua Islands in the Bahamas, and Barbados, West Indies. We define the ages of sea-level events from the mean ages of individual stratigraphic units, and our quoted errors reflect the external reproducibility of such ages rather than being propagated from analytical uncertainty. This approach should reflect the total uncertainty in the age estimates, including any correction error and non-ideal U-series isotope behavior.

Our results indicate:

1) The use of age-correction decay equations and high-density sampling in a detailed stratigraphic context is crucial for accurate and precise dating of corals and the resolution of rapid sea-level change.
2) Ages that cannot be reconciled with the stratigraphic context must be rejected.
3) Sea level was above modern for 3 relatively brief periods during the last Interglacial at 122, 118 and 114 ka.
4) A wave-cut surface in the Bahamas unequivocally demonstrates that sea level fell to near modern between 122 and 118 ka.
5) There is little evidence of sea levels above modern prior to ~ 123 ka.

Coral Geochronology

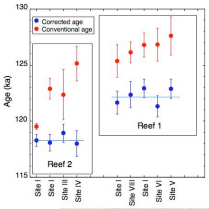
U/Th dating of corals is problematic because corals absorb excess ^{234}Th and ^{230}Th produced by decay of uranium in the surrounding environment. Thompson et al. (3) developed new equations to correct for such radiogenic isotope addition, but recently concerns were raised about the reproducibility of both conventional and corrected coral ages (4). Here we test the reproducibility of U-series coral ages at multiple spatial scales by comparing: Replicate ages for individual corals (length scale: cm); ages of corals within a stratigraphic unit at a particular site (length scale: m); ages of stratigraphic units between different sites at a particular location (length scale: m to km) and ages of stratigraphic units between different locations (length scale: 100's to 1000's of km).

Our results indicate:

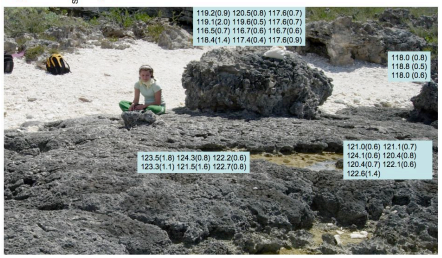
1) Differences between replicate ages for individual corals can be somewhat larger than the analytical uncertainties for both conventional and corrected ages, because the isotopic composition of the corals are not strictly homogenous. Both age calculations can be compromised by gain or loss of bulk U or Th.
2) Means of replicate corrected ages for individual corals from the same stratigraphic unit agree. Conventional ages do not, indicating that uncorrected ages are unreliable.
3) For corrected ages, differences between corals from the same stratigraphic unit are often similar to differences between sub-samples for a single coral, indicating that all the corals in these units are very close to the same age and that corrected ages are generally robust. This is not true for conventional ages, suggesting uncorrected ages are less reliable.
4) For corrected ages, mean ages of stratigraphic units agree within error between sites, indicating such mean ages are robust. Uncorrected ages fail to resolve age differences between stratigraphic units.
5) Stratigraphic units of identical corrected age can be found at Barbados, West Indies; San Salvador, Bahamas; and Great Inagua, Bahamas, suggesting that the age correction equations are widely applicable.

Great Inagua, Bahamas

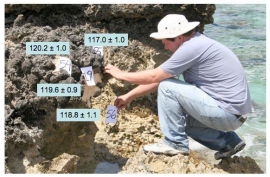
The Last Interglacial deposits on Inagua are predominantly intact and in place. A well-documented erosional surface, which can be traced for at least several kilometers, records a fall of sea level in the midst of the Last Interglacial (5).



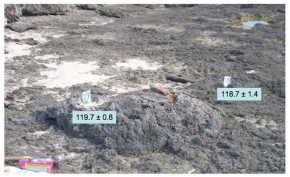
Site	reef	sample	number of ages	mean corrected Age (ka)	± 2SE	mean conventional Age (ka)	± 2SE
Site I	Reef 1	single coral	6	122.9	0.8	126.8	1.1
Site I	Reef 1	single coral	7	121.7	1.0	125.4	1.4
Site I	Reef 2	single coral	3	118.3	0.5	119.5	0.3
Site I	Reef 2	single coral	12	118.1	0.7	122.9	0.9
Site III	Reef 2	multiple corals	3	118.9	0.8	122.4	2.3
Site IV	Reef 2	multiple corals	7	118.0	1.1	125.1	1.5
Site V	Reef 1	multiple corals	9	122.9	0.9	127.6	1.7
Site VI	Reef 1	multiple corals	6	121.3	0.9	126.8	1.5
Site VIII	Reef 1	multiple corals	4	122.4	1.2	126.1	0.9



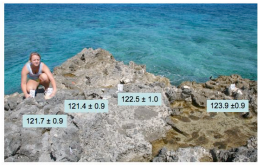
Site I: Massive in-situ coral heads of Reef 2 sit on wave-cut surface of Reef 1



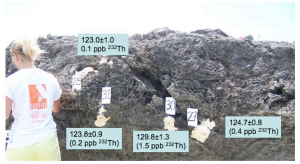
Site IV, Reef 2, 4 ages from the same coral



Site IV, Reef 2 corals on Reef 1 surface



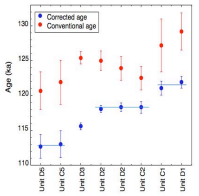
Site VII: reef crest deposits



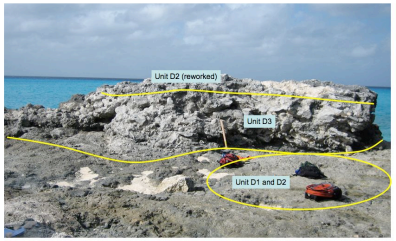
Site V: bulk Th addition, indicated by elevated ^{232}Th, increases ages

San Salvador, Bahamas

A similar erosional surface, although not as well preserved, is present on San Salvador Island, more than 300 km from Inagua. The Bahamas are relatively stable tectonically, subsiding gently at a rate of perhaps 1 m/100 ka.

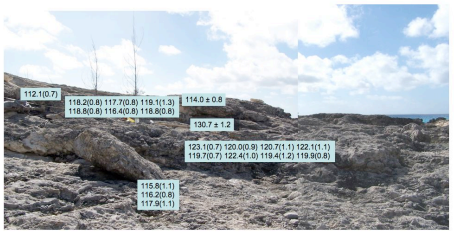


Site	Stratigraphic Unit	Number of ages	Mean corrected Age (ka)	± 2SE	Mean conventional Age (ka)	± 2SE
Profile D	Unit D5	2	112.7	1.7	120.7	2.7
Profile C	Unit C5	2	113.0	1.9	121.9	3.2
Profile D	Unit D3	14	115.6	0.5	125.4	0.9
Profile D	Unit D2	9	118.1	0.5	125.0	1.4
Profile D	Unit D2	7	118.3	0.6	123.9	1.7
Profile C	Unit C2	7	118.3	0.8	122.5	1.7
Profile C	Unit C1	7	121.1	1.0	127.2	3.8
Profile D	Unit D1	4	121.9	0.8	129.2	2.7



Profile D: Reef crest deposits on wave-cut surface.

Profile D: encrusting corals (Unit D2) on wave-cut surface (Unit D1).

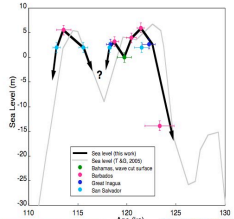


Profile C ages

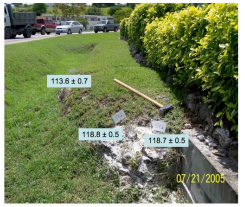
Barbados, West Indies

The coral terraces of Barbados are uplifted, allowing a greater range of sampling elevations. However, many of the reef deposits are not demonstrably *in-situ*. Several sections of the Last Interglacial deposits yield a range of ages, suggesting significant reworking of corals.

Nevertheless, sections with coherent ages can be found.



Terrace top 1 : 147-150 initial δ^{234}U



Terrace top 2

Terrace top 3

19 m below terrace top

Acknowledgements

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