Paleosea-Level Records from Late Quaternary Coral Reef Terraces on Araki Island, Vanuatu; Comparison With Previous Results from Huon Peninsula, Papua New Guinea

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Abstract

New $^{230}Th/^{238}U$ ages for precisely leveled fossil corals from Araki Island, Vanuatu, generally corroborate MIS 3 and 4 paleosea-level estimates from the Huon Peninsula (HP), Papua New Guinea. Corals have been essential for paleosea-level reconstructions and their timing because they provide such precise U-series dates. However, paleosea-level estimates from uplifted corals rely on inferring tectonic uplift rates in order to subtract uplift from coral elevations. Uplifted coral reefs at central Vanuatu and Western Solomons exemplify the extremely abrupt tectonic rate changes that forearcs can undergo. If uplift rate changes are not detected and taken into account then paleosea-level estimates could be wrong by tens of meters. Araki Island, located 2,500 km and two plates away from the Huon Peninsula is tectonically independent. Araki should share a similar paleosea-level history with HP, including Global Isostatic Adjustments, and other water-loading influences, but should be tectonically different. Assumptions similar to those used to infer HP sea-level estimates are applied for the Araki mid-Holocene, MIS 5c, and MIS 5e paleosea-levels in order to constrain MIS 3 and 4 paleosea-levels. Before and during MIS 5e (~130-120 ka) until MIS 5c (~106 ka) Araki subsided at ~3 mm/yr. At or soon after 106 ka Araki abruptly began uplifting at a mean rate of ~1.65 mm/yr. This ~1.65 mm/yr mean uplift rate appears to have prevailed until ~25-30 ka after which uplift accelerated to a mean rate of ~4.6 mm/yr. These uplift rates imply MIS 3 and 4 paleosea-levels very similar to those inferred from the HP reef terraces of similar ages. The abrupt changes in vertical tectonics that our coral ages and elevations imply for Araki Island offer insights regarding the remarkably rapid tectonic variability and possible mechanisms that control convergent margin tectonics as well as the challenges involved in using the data for paleosea-level reconstructions.

Introduction

Araki, Vanuatu

- Small island representative of outer forearc islands at the convergence of Pacific and Australian plates (Figure 1)
- Undergoing rapid vertical tectonics due to subduction of two massive underwater features, the DEZ and the WTM
  - Reduction of plate conversion rates due to back-arc reverse faulting
  - Rapid thickening and uplift of the forearc probably due to shortening and volume of underlying ridges and seamounts
  - Very shallow trench
- Vertical changes over time recorded by coral fossils, which grow near sea level and are able to be precisely dated using ^{230}Th dating
- Uplift model uses fossil coral data and known paleosea-level constraints to estimate uplift rates and sea level history
  - Sea level history compared to nearby records from Huon Peninsula, Papua New Guinea (PNG) (Figure 2)
  - Model adjusted until a best fit with PNG sea level estimates is found

Samples

- Fossil corals were collected with hammer and chisel in 2005 by Fred Taylor and Nick Freiburger
- Elevations of corals measured using a TopCon level, leveled from highest living corals with loops closed to within a few cm
  - Elevation error conservatively estimated at ±1 m

^{230}Th dating of samples

- Conducted at Shepherd Labs at University of Minnesota
- Expands on dataset begun by Nick Freiburger (2006) and Tyler Carlson (2008)
- Fifty-nine samples, ranging from 32.16 ± 0.06 to 141.27 ± 0.3 ka and 32 ± 1 to 183 ± 1 meters above sea level
- Acceptable $\delta^{234}U$ values: 147‰ + 8‰ and – 10‰

Sampling of dataset

Sample Number	^{238}U (ppb)		^{232}Th (ppt)		$^{230}Th/^{232}Th$ (atomic x10^{-6})		$\delta^{234}U^*$ (measured)		$^{230}Th/^{238}U$ (activity)		^{230}Th Age (ka) (uncorrected)		^{230}Th Age (ka) (corrected)		$\delta^{234}U_{Initial}$ (corrected)		Elevation (m)
G	2885	32	13.0	7.0	1.1E+06	5.7E+05	127.7	0.5	0.2895	0.0003	32.16	0.04	32.16	0.04	139.8	0.6	39.3
AA	3759	45	231.1	8.9	7.8E+04	2.9E+03	127.1	0.3	0.2926	0.0003	32.59	0.03	32.59	0.03	139.3	0.4	52.3
W[ab]	3228	5	15.9	7.8	1.1E+06	7.1E+05	125.8	1.8	0.3001	0.0009	33.61	0.13	33.61	0.13	138.4	2.0	51.7
Q[a]	2632	4	37.0	7.2	3.6E+05	7.0E+04	127.1	2.1	0.3038	0.0009	34.08	0.14	34.08	0.14	140.0	2.3	35.9
R	2789	33	2.4	7.8	6.0E+06	2.0E+07	125.9	0.4	0.3066	0.0004	34.44	0.05	34.44	0.05	138.8	0.5	36.2
K[a]	2634	3	81.2	9.1	1.6E+05	1.8E+04	126.9	1.8	0.3071	0.0008	34.53	0.12	34.53	0.12	139.9	2.0	32.7
P	2532	27	24.6	11.0	5.2E+05	2.3E+05	125.2	0.5	0.3080	0.0003	34.66	0.04	34.66	0.04	138.0	0.5	36.4
S[a]	2616	4	88.5	8.4	1.5E+05	1.4E+04	129.6	1.8	0.3093	0.0010	34.71	0.15	34.71	0.14	143.0	2.0	37.2
A	2386	24	12.4	5.7	9.8E+05	4.5E+05	125.6	0.4	0.3086	0.0003	34.72	0.04	34.72	0.04	138.6	0.5	34.6
L	2269	23	242.1	8.1	4.8E+04	1.5E+03	125.2	0.4	0.3088	0.0003	34.77	0.04	34.77	0.04	138.1	0.4	38.5
M	2464	32	139.2	8.3	9.1E+04	5.3E+03	125.2	0.5	0.3104	0.0003	34.98	0.04	34.98	0.04	138.2	0.6	36.6
N	1933	18	125.4	5.9	7.9E+04	3.6E+03	125.6	0.4	0.3116	0.0003	35.11	0.04	35.11	0.04	138.7	0.4	36.6
C	2712	34	0.2	8.1	7.2E+07	3.0E+09	125.1	0.5	0.3144	0.0003	35.51	0.04	35.51	0.04	138.3	0.6	32.4
O[a]	2305	3	22.0	6.8	5.4E+05	1.7E+05	126.6	1.7	0.3151	0.0008	35.59	0.13	35.59	0.13	140.0	1.9	36.6
E[a]	1290	2	38.9	4.5	1.7E+05	2.0E+04	123.8	1.6	0.3184	0.0008	36.14	0.12	36.14	0.12	137.1	1.8	38.4
B	1915	21	61.2	8.0	1.7E+05	2.1E+04	126.3	0.4	0.3200	0.0003	36.21	0.05	36.21	0.05	139.9	0.5	36.6
X[ab]	2559	4	27.7	11.7	5.2E+05	2.3E+05	126.3	2.0	0.3377	0.0010	38.61	0.16	38.61	0.16	140.8	2.2	53.6

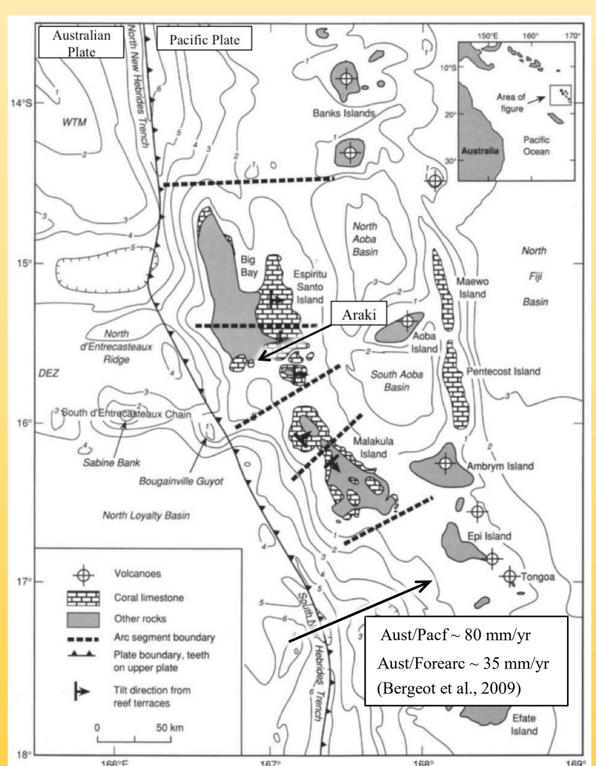


Figure 1: Map of Central New Hebrides island arc, showing major islands and bathymetry (Adapted from Taylor, 1992).

Comparison Curve

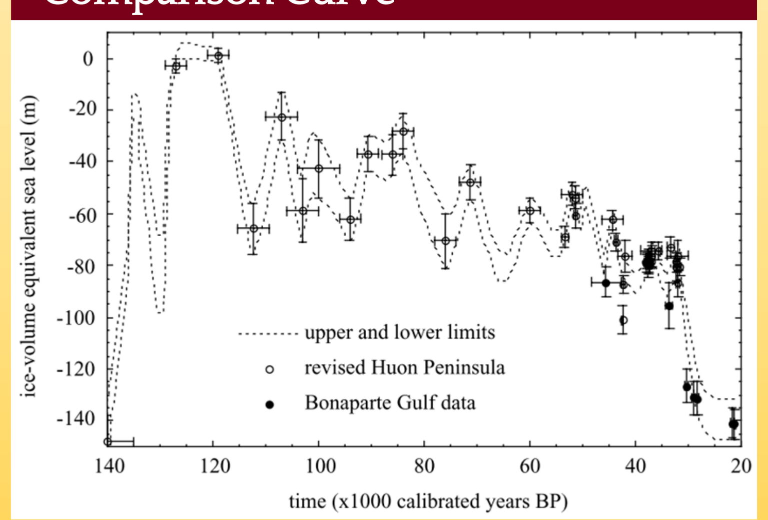


Figure 2: Ice-volume equivalent sea level (sea level associated with the change in ocean volume due to growth or melting of land-based ice sheets) curve derived from Huon Peninsula uplifted corals and sediments from Bonaparte Gulf (Lambeck et al., 2002)

Uplift Model

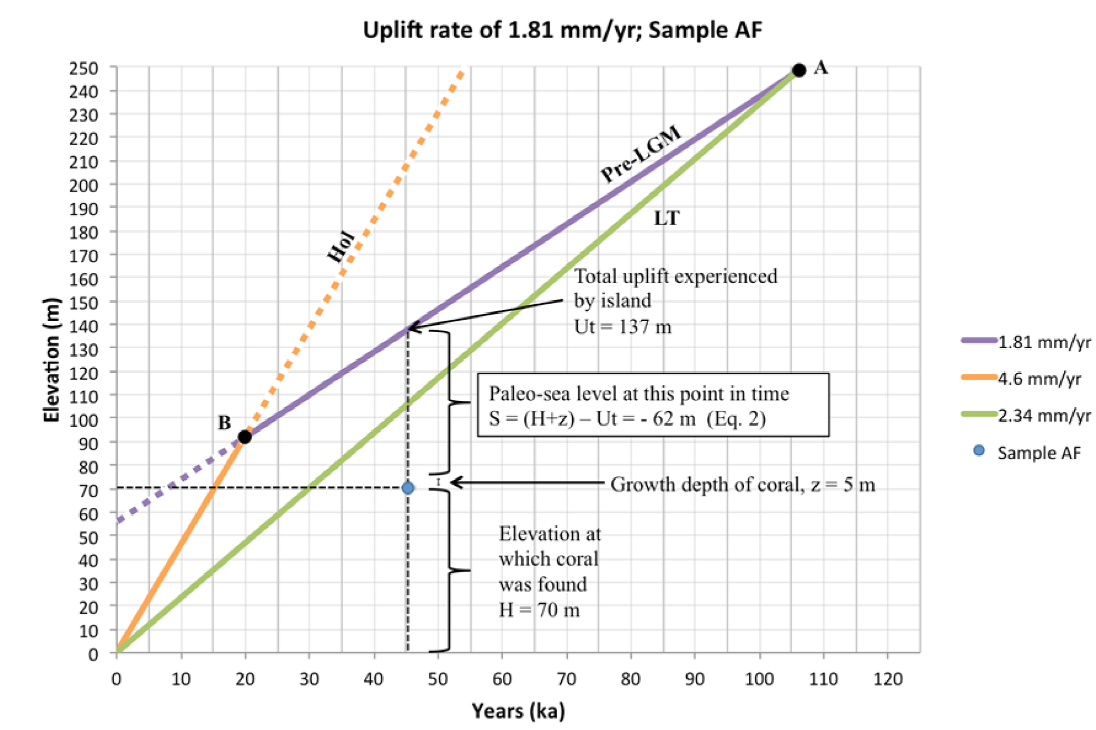
Model composed of three important segments:

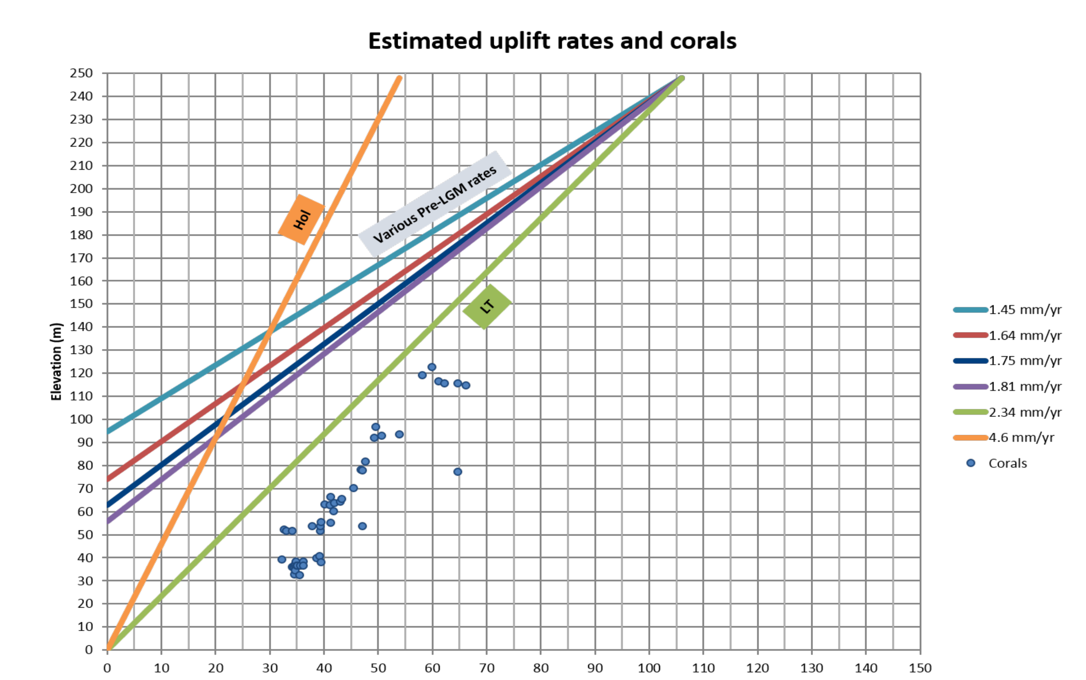
- Long-term uplift rate since ~106 ka (LT)
  - **2.34 mm/yr**, from Urmos (1985)
  - Begins at 106 ka, when Araki switched from subsidence to uplift
- Uplift rate since ~20 ka (Hol)
  - **4.6 mm/yr**, from present dataset, combined with drilling results from nearby islands (Taylor et al., (2005); Cabioch, (2003))
  - Can assume this rate extends at least 20 ka back
- Uplift from ~20 – 106 ka (Pre-LGM)
  - Determined in the present model, based on how far back the Holocene rate extend

Model can be used to determine sea level at time of coral growth (S) for each sample, using the following equation:

$$S = (H + z) - Ut$$

where H is the elevation at which the coral was found, z is the growth depth of the coral, and Ut is the total uplift experienced by the island since the growth of the coral (Chappell et al., 1996).



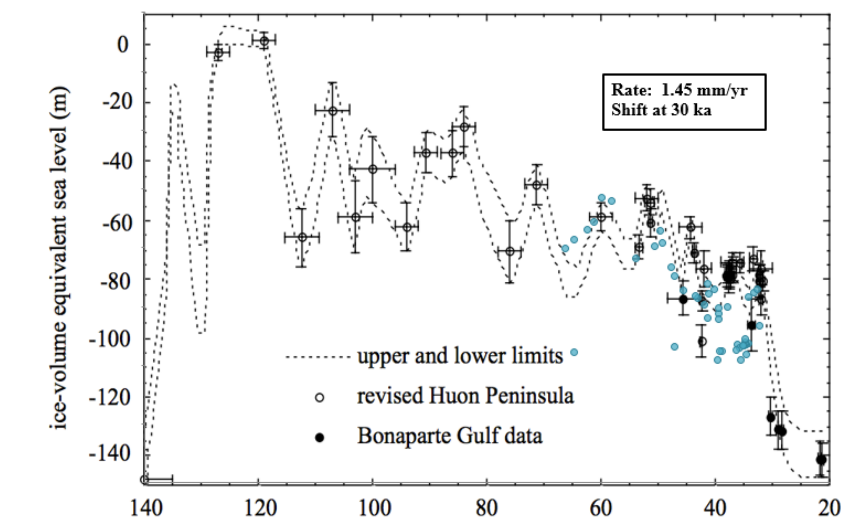


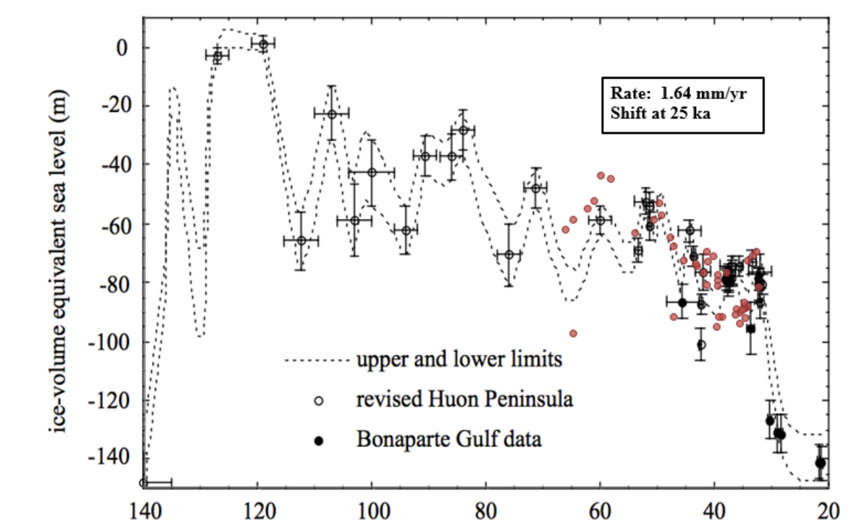
Sources of Error

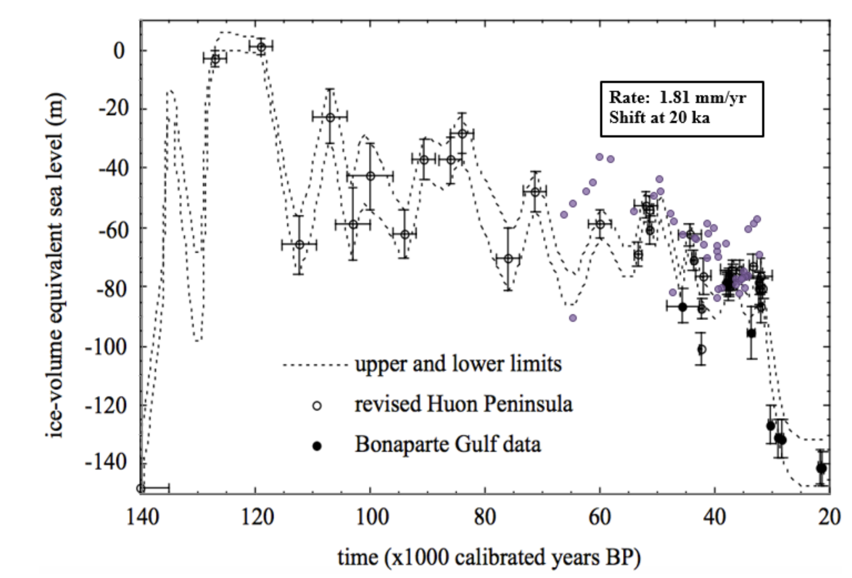
- Growth depth of corals, assumed to be 5 m below sea level
- Age of the peak elevation of Araki, based on Urmos (1985)
- Analytical uncertainty of ages
- Error in field surveying, conservatively estimated at ± 1 m
- Assumption of tectonic linearity

Inferred Sea Levels

Sea levels calculated using various Pre-LGM rates derived from the model, compared to HP sea level curve from Lambeck et al. (2002).







Predicted sea levels better fit the existing curve at rates of about 1.4 to 1.6 mm/year, indicating a shift to the faster Holocene uplift rate at about 25 – 30 ka. In large part this record confirms the HP paleosea-level for MIS 3. There are tectonic ambiguities in the Araki record, but tectonic rate variability may exist for HP too. Given the importance of the MIS 3 period, there are plans to date additional Araki corals with better paleosea-level depths.

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References:

N. Bergeot et al. (2009) *Journal of Geophysical Research,* 114, BO6405.
J. Chappell et al. (1996) *Earth and Planetary Science Letters*, 141 (1-4), 227-236.
K. Lambeck and J. Chappell (2001) *Science*, 292 (April), 679-686.
F. W. Taylor (1992) *Proc. Ocean Drill. Program Initial Rep,,* 134, 33-42.
J. P. Urmos (1985) *Cornell University.*