

IAEA CRP Mission to Palau, 24 Nov – 5 Dec 2008

Field Notes

Mission members (on the vessel *Reel Time*, based out of Koror, Palau):

- Rob Dunbar (Stanford University) – dunbar@stanford.edu
- Dave Mucciarone (Stanford University, USA) – dam1@stanford.edu
- Stéphanie Reynaud (Centre Scientifique de Monaco) – sreynaud@centrescientifique.mc
- Saber Al-Rousan (Marine Sciences, University of Jordan) - s.rousan@ju.edu.jo
- Captain Jim Persinger (owns Reel Time and Jim's Boat Repair, wife & business partner is Alodia) - jim@palaunet.com
- Chef Rene Menz (owner of Krämers restaurant in Koror – after the German anthropologist)
- Gonzo (first 3 days), staff of Coral Savers Foundation
- Singhi (from day 3rd to end of mission) PADI dive instructor, founder of Coral Savers Foundation) - earth@coralsavers.org
- Joan-Albert Sanchez-Cabeza (IAEA-MEL, Monaco) – j.a.sanchez@iaea.org

Mission objectives: To recover 8-cm diameter diamond drill cores from large colonies of *Porites lutea* or *Diploastrea sp.* for climate/environmental reconstruction over the past 200 years. Dead corals are suitable if long records can be obtained. Live corals are sampled with extreme care and holes are infilled with coral rubble and sand as a protective measure against bioerosion. All scientists on the mission are trained experts in working in reef settings with conservation and protection objectives. The proposed locations given in the site list below are approximate. At the conclusion of the mission a detailed full report of all samples collected will be delivered to the Koror and Palau authorities. The following list shows what we submitted to the Palauan authorities for the acquisition of our permits.

Initial list of possible Sampling Sites (Note: coral cores will not be collected at all sites):

1. Ulang Channel – large dead (ca. 1998) *Porites lutea* colony in channel
2. North of outer Ulang channel entrance – large *Diploastrea heliopora*. Both sites 1 and 2 roughly at 7° 17.2'N, 134° 15.3'E
3. “Coral Gardens” - *P. lutea*, roughly 7° 7.5'N, 134° 22.3'E
4. “Bait Ground” (Rock Islands) - *P. lutea*, roughly 7° 15.7'N, 134° 23.4'E
5. Ngaragabel area - *P. lutea*, roughly 7° 25.2'N, 134° 26.5'E
6. Koror side of KB channel - *P. lutea*, roughly 7° 21.0'N, 134° 30.0'E
7. West of Ngeremduu Bay - *P. lutea*, roughly 7° 31.1'N, 134° 27.5'E
8. Ngeralang Bay - *P. lutea*, roughly 7° 40.7'N, 134° 34.5'E

Timeline/Itinerary: We propose to visit the sites above in approximately the order listed. We do not propose to sample corals at all sites. The exact sampling locations will be determined after survey work. We conduct surveys by snorkel or SCUBA depending on water depth and search for appropriate coral colonies for sampling.

Narrative and notes:

November 24- Mission participants arrive safely at Koror, Republic of Palau. Saber Al-Rousan will arrive 2 days later because of a last minute change in flights made by IAEA.

November 25- The team gets ready for the mission. We meet Pat Collin (CCRF) who provides useful directions to find large *Porites lutea* or *Diploastrea sp.* samples. Joan-Albert Sanchez-Cabeza and Rob Dunbar spend most of the day meeting and discussing with Palau Government and Koror State staff. The drill is assembled and successfully tested.

November 26- Joan-Albert Sanchez-Cabeza has further meetings with Palau Government staff and a verbal agreement for sampling is obtained. Departed from Sam's Tours docks at about 1500 for Ulang Channel. We arrived on site at 1630. Cruised in channel at near high tide and located possible large *Porites* head. Snorkeled late in the day with sizable chop and strong tidal current and did not locate large heads. Spent the night tied up to north Ulang Channel marker buoy.

November 27- Woke up at 0600 and began surveying Ulang Channel by snorkel. Located large dead *Porites* head described to us by Pat Collin (CCRF). This coral is dead and appears to have been killed by the 1998 bleaching event (as were many corals in Palau). Pat is certain it died then. The coral consists of two main hemispherical lobes that have merged giving it an elongate shape. It is about 9 m long by 6 m wide. At high tide the top is at about 40 feet. The base, which is somewhat undercut, is at about 59 feet. So, it may be possible to recover 5 meters here. As for the rest of the channel, there are other dead *Porites* colonies but they are quite a bit smaller, perhaps less than 2-3 meters. There are some living *Porites* heads as well, many of them less than 1 meter. The innermost portion of the channel is mostly sand. Significant coral cover begins about 2/3 of the way in from the entrance and appears to increase towards the channel mouth.

After departing the inside portion of Ulang Channel we used SCUBA to dive along the steep wall just north of the Ulang Channel protected area boundary marker. We dove from this boundary marker south towards the channel entrance surveying for living *Porites* and *Diploastrea* heads. The *Porites* heads here were mostly less than 120 cm in height. There were some *Diploastrea* in the range of 1 to 2 meters. Since growth rates in this spp. are typically lower than in *Porites* it is possible that some of these heads contain records as long as 200 years. Overall, the reef here looks quite healthy. Dove to a maximum depth of 55 feet and shot about 22 minutes of HDV.

We departed Ulang Channel for the "Coral Gardens" in Pellelui at 1130. Arrived on site at 1430 and took Saber Al-Rousan aboard in main channel. We dove at two sites here, the first to the south in Pellelui and the second in the channel to north heading into Koror state. In Pellelui, we found a number of likely targets for drilling, e.g., several *Porites* heads that were either alive or dead (1998?) and on the order of 2 meters in height. In the Koror state channel here we didn't find anything worth drilling. We spent the night in the Rock Islands area moored to the top of a Japanese shipwreck from WWII.

November 28- Woke up at 0600 and began to survey by snorkel in the "bait grounds" area of the Rock Islands. Normally the channels between the rock islands are too deep to support significant coral growth but there are some shallow ridges at some locations. Many of these support patch reefs that contain *Porites* but none of them are large enough for drilling. We then returned to Koror harbor so that Joan-Albert Sanchez-Cabeza could proceed with obtaining copies of our research permits, from the Palau Government and Koror State. While at the dock we replaced empty dive tanks as well as water. We also met again with Pat Collin and received some aerial photos showing targets in the Rock Islands as well as at Ngaragabel.

At 1000 we received word that we would have permission to drill in Koror state, including in the Ulang Channel.

We left port for the Ulang Channel at about 1100 and arrived on site at 1300, where we were controlled by the “Rangers” (Marine Resources Department). It took about 2 hours to get a 3 point anchoring system in place and to get the drill set up for its first use. We started drilling hole U-1 (Ulang Channel) in the large dead *Porites* that we surveyed on November 27. The core came up in 5 main pieces (and 2 smaller pieces) with a total length of about 190 cm (estimated). The drill bit barrel became jammed at about 1700. We had to stop work for the day.

November 29- Woke up at 0630. Started first by resetting one anchor line that had come loose during the night. Next tried using pipe wrenches with cheater bar to turn drill, but the drill rod was damaged. Success came with arranging a hose system to deliver muriatic acid to drill bit. The acid worked for about 20 minutes when the drill was all of a sudden turnable. Drill was then retrieved and returned to surface to undo the extra tight joints that the recovery efforts had created. At 1100 we began a new drill hole on the same head – this one designated U-2.



*Figure 1- View of large dead *Porites lutea* head drilled in Ulang Channel, Koror State, Palau on November 28 and 29, 2008. This coral is purported to have died during the 1998 bleaching event. There is relatively little bioerosion or recolonization by other corals. This view shows the channel side lobe with the coral head top at about 41 feet. The depth of the sand channel to the left is 61 feet. We were hoping that the undercut area beneath the coral head represented the extension of the coral growth down to a total depth of 20 feet but we reached a coral bottom in core U-2 at 278 cm. This head is nevertheless likely worth additional drilling. The divers are preparing to drill core U-2. Currents are strong, particularly during outgoing tide.*

***** Cores U-1 and U-2 collected on 28 and 29 November 2008, from large dead *Porites* colony at 7°17.153’N, 134°15.016’E in Ulang Channel, Palau, on November 28 and 29, 2008. Water depth to bottom of channel = 61 feet. Water depth at top of coral = 41 feet. We were told by Pat Collin that this coral died during the 1998 bleaching event. There does not appear to be much bioerosion here so the topmost portion of U-2 is very likely 1998 or within a few years of this. Core U-1 = 1.88 m (7 pieces); Core U-2 = 2.72 m (6 pieces).**



Figure 2- View of large dead *Porites lutea* head drilled in Ulang Channel, Koror State, Palau on November 28 and 29, 2008. This coral is purported to have died during the 1998 bleaching event. There is relatively little bioerosion or recolonization by other corals. This view shows the head viewed from above. The divers are drilling core U-2 on top of the larger (channel side) lobe. The lobe has an effective diameter of about 6 meters and is about 3.5 m tall.



Figure 3- Coral core U1.

U-2 was drilled to a depth of about 273 cm until a clear coral bottom was recovered. Based on surveying this lobe it seems as though we should have exceeded 3 meters. We drilled U-1 and U-2 from the channel side lobe of this 2-lobe *Porites*. Perhaps if we drilled the other lobe (on the channel edge side lobe) we could get a longer coral? This is a possible target for a future drilling expedition. We then moved to a smaller coral head (80 cm tall) immediately adjacent to the big head to recover an overlap core to extend from about 1990 to 2008. Pat Colin informed us that he has temperature loggers since about 2001. We drilled U-3 and U-4 from this head under conditions of strong incoming tidal current flow. All 4 holes were filled with rubble and sand, and we left Ulang Channel with our objective accomplished. We left Ulang at 1730 and proceeded across the reef to moor for the night on the mast of Iro in the Rock Islands. Note that no water samples were collected here (but were collected later).



Figure 4- Coral core U2.

***** Cores U-3 and U-4 collected on 29 November 2008, from small live *Porites* colony at 7°17.153’N, 134°15.016’E (immediately adjacent to the large dead coral that we drilled U-1 and U-2 from). These cores were collected from a water depth of 39 feet, e.g., within several feet of the water depth of the top of the big dead *Porites*. They were collected to allow us to match a record extending to 2008 from the dead top of the big coral with perhaps 10 to 15 years of overlap for precise cross-dating. Also, Pat Colin has temperature loggers in Ulang channel since about 2001. The current was very strong when we drilled here. The 2nd core is short and is a single piece. The 1st core is from the same small colony but is longer and came up in two pieces. Core U-3 = 0.44 m (2 pieces); Core U-4 = 0.18 m (1 pieces).**



Figure 5- View of small, live *Porites lutea* head drilled in Ulang Channel, Koror State, Palau on November 29, 2008. This live coral was short-drilled to recover a 20+ year record that can be cross-dated with U-1 and U-2 to bring the chronology up to 2008. The coral was at a depth of 40 feet, the same as the top of the big dead head. Cores U-3 and U-4 were collected from this colony.



Figure 6- Full view of coral cores U3 and U4.

November 30- Woke at 0630 and prepared for a dive on Iro. Dove at 0800. Max depth 104 feet, about 10 feet above a murky and silty bottom. Main deck was at about 70 feet with masts and rigging extending to about 30 feet. Next we departed Iro for a small bay in the Rock Islands that we were pointed to us by Pat Collin. The bay is just west of soft coral arch and has several patch reefs with abundant *Porites* colonies. Some of these are as much as 1.5 to 2 meters in height. We decided to drill 2 colonies here because of the semi-enclosed nature of this small bay, a feature that may amplify rainfall signals. Two *Porites* heads were drilled. The two heads were about 60 feet east of the ship's position and were about 15 feet apart. These cores are designated RI-5 and RI-6. Stephanie Reynaud drilled RI-5 and Saber Al-Rousan drilled RI-6. Water samples from the sea and drip water from the rock island walls that surround this little bay were collected.

***** Cores RI-5 and RI-6 collected on 30 November 2008, from two different and adjacent live *Porites* colonies at 7°16.248'N, 134°23.024'E in a small embayment in the Rock Islands just to the west of soft coral arch, Koror State, Palau. The water depth at the top of both corals is about 8 feet at low tide. Core RI-5 = 1.40 m (4 pieces); Core RI-6 = 2.58 m (7 pieces). Seawater and drip water samples collected and labeled RI.**



Figure 7- View of live *Porites lutea* head drilled in the Rock Islands, Koror State, Palau, on November 30, 2008. This head is quite shallow at low tide (<10 feet) and is about 2 meters in height off the sand bottom. Core RI-5 was drilled from this head.

Left the site at 1500, en route to Koror to take on water, fuel, and more lead weights. Arrived Koror at 1600 and spent 2 hours doing port call. Then moved off to a sheltered cove for the evening.



Figure 8- View of live Porites lutea head drilled in the Rock Islands, Koror State, Palau on November 30, 2008. This head is quite shallow at low tide (<10 feet) and is about 2 meters in height off the sand bottom. Core RI-6 was drilled from this head.



Figure 9- View of live Porites lutea head drilled in the Rock Islands, Koror State, Palau on November 30, 2008. This head is quite shallow at low tide (<10 feet) and is about 2 meters in height off the sand bottom. Core RI-6 was drilled from this head. This image shows the same borehole as in Figure 5 but after the hole was been filled with dead coral rubble to prevent bioeroders from entering the hole.



Figure 10- Coral core R15.



Figure 11- Coral core R16.

December 1- Woke at 0615 and proceeded to a little patch reef at Ngaragebal (pronounced “Narabal”). Snorkeled for 30 minutes. Lots of *Porites* in area “A” on Pat Collins’ photos. The patch reef is about 80 m in diameter and shoals at about 8 feet. Virtually all of the *Porites* here are highly lobate in growth habit, with lobes ranging from baseball to basketball in size. This doesn’t bode well for drilling but we tried a head on the easternmost edge of the patch reef. The first hole ran into a lobe boundary at about 50 cm. With the second hole we collected over a meter before hitting a lobe boundary. We then stopped drilling, collected a water sample, and headed north to Ngeralang.

***** Cores NGB-7 and NGB-8 collected on 1 December, 2008, from a live *Porites* colony at 7°24.386’N, 134°26.115’E on a small patch reef in the exposed open lagoon of Palau (Ngaragebal area) some distance offshore, Koror State, Palau. The water depth at the top of this coral is about 16 feet at mid tide. Core NGB-7 = 0.48 m (1 piece); Core NGB-8 = 1.01 m (2 pieces).**

*****Seawater sample collected from 1 meter depth and labeled NGB.**

In the afternoon, we arrived at a large area of patch reefs in Ngeralang Bay. Upon surveying several of these areas for ~90 minutes it seems that most of the *Porites* here are of the lobate variety, similar to what we found at Ngaragebal. There are some perfect hemispheres of *P. lutea* but all of these are less than 80 cm across and high. At 1600 we began drilling a 2 meter tall live *Porites* colony that was slightly less lobate. We recovered about 1.5 meters and then drilled a small (75 cm) *Diploastrea heliopora* colony nearby, on Stephanie Reynaud suggestion. We will use this to conduct a comparative analysis of the environmental signal recording capabilities of these two species. No water samples were collected.



Figure 12- View of live *Porites lutea* head drilled in Ngaragebal, Koror State, Palau on December 1, 2008. This head is quite shallow at low tide (<6 feet) and is about 2 meters in height off the bottom. Cores NGB-7 and NGB-8 were drilled from this head.



Figure 13- Coral core NGB7.



Figure 14- Coral core NGB8.

*** Core NL-9 was collected on 1 December, 2008, from a live *Porites* colony at 7°39.413"N, 134°33.907"E on a patch reef in the outer open lagoon of Palau some distance offshore, Ngardmau, Palau. The water depth at the top of this coral is about 8 feet at mid tide. Core NL-10 was collected on 1 December, 2008, from a live *Diploastrea heliopora* colony at 7°39.413"N, 134°33.907"E on a patch reef in the outer open lagoon of Palau some distance offshore, Ngardmau, Palau. The water depth at the top of this coral is about 13 feet at mid tide. Core NL-8 = 1.51 m (3 pieces); Core NL-10 = 0.6 m (1 pieces).

We finished drilling at about 1730 and headed north under rapidly diminishing light to a difficult channel entrance to the port of Ollei, northernmost Babeldoab. Spent the night tied up at the Ollei pier.

December 2- Woke at 0600 at the Ollei dock and had a short look around. We departed at 0650 for Ngeremduu Bay. Our target was a *Porites* coral record that may track outflow of the 3 rivers that drain into the Bay. This is Palau's largest river mouth/estuarine system. We arrived at Ngeremduu Bay at 0930 and began surveying by going close to the bay entrance.

There are some walls here that go from 120' to <5'. We did not observe any large *Porites* colonies but we did find several *Diploastrea heliopora* colonies approximately 1 m tall. We selected one of these to drill and began work at 1100. We drilled core ND-11 at this site. There was a significant salinity gradient between the uppermost 50 cm of the water column and the deeper waters. We collected two water samples here, ND surface water (in the low salinity layer) and ND deeper water (collected from the base of the target coral head). The bottom here is a slope rising to a reef flat. The slope down to at least 60' is covered with silt from the rivers that enter into Ngeremduu Bay. Stéphanie noticed an *Acropora* colony that was live but with whitened branches for the outermost 8 cm. These tissues appear intact but likely do not contain zooxanthellae. Several pictures were taken.

******* Core ND-11 was collected on 2 December, 2008, from a live *Diploastrea heliopora* colony at 7°30.689"N, 134°29.447"E adjacent to a shallow reef flat in Ngeremduu Bay, Ngatpang State, Palau. The water depth at the top of this coral is about 7 feet at mid tide. Core ND-11 = 95 cm (2 pieces).**



Figure 15- View of live *Porites* head drilled in Ngeralang, Ngardmau State, Palau on December 1, 2008. This head is quite shallow at low tide (<6 feet) and is about 2 meters in height off the bottom. Core NL-9 was drilled from this head.

After Ngeremduu Bay, we set off south to drill *Diploastrea* colonies near the mouth of the Ulang Channel, per Pat Collin's suggestion. Pat has a hobotemp water temperature logger installed at this site. We can get this data for coretop T calibration purposes. The corals here were surveyed earlier by us on November 28 and are just north of the marker buoy for the northern outer (channel entrance side) boundary of the Ulang Channel protected area. We arrived on site at 1400 and proceeded to drill starting at 1500. 2 cores were collected, U-12 and U-13, from the same ~2 meter tall head of *Diploastrea heliopora*. This head has a large dead spot just on the crown (top) of the colony, a feature seen in nearly all of the larger *Diploastrea* colonies at this site. Perhaps this is a remnant of the 1998 bleaching event? We drilled U-12 straight down starting in the dead area and continuing as deep into the coral as possible. Core U-13 was drilled starting at the top of the coral but through a live portion and angled in towards the center. After drilling about 90 cm of U-13, the core intersected the first drill hole (U-12), providing a good way to cross-date and match these two cores. A water sample was collected from the coring site.

*** Cores U-12 and U-13 were collected on 2 December, 2008, from a live *Diploastrea heliopora* colony at 7°17.186’N, 134°14.403’E just north of the northern Ulang Channel protected area marker buoy, Koror State, Palau. Core U-12 was drilled vertically starting from a dead patch on the crown of the coral. Core U-13 was drilled from the top of this colony as well but starting from a live patch at the top of the colony. We guess that the top of U-13 is modern while the top of U-12 may be the year 1998. The water depth at the top of this coral is about 16 feet at mid tide. Core U-12 = 134 cm (4 pieces); Core U-13 = 65 cm (2 pieces).



Figure 16- Coral core NL9.



Figure 17- View of small live *Diploastrea heliopora* head drilled in Ngeralang, Ngardmau State, Palau on December 1, 2008. This head is at 13 feet water depth at mid-tide and is about 60 cm high. Core NL-10 was drilled from this head.



Figure 18- Coral core NL10.

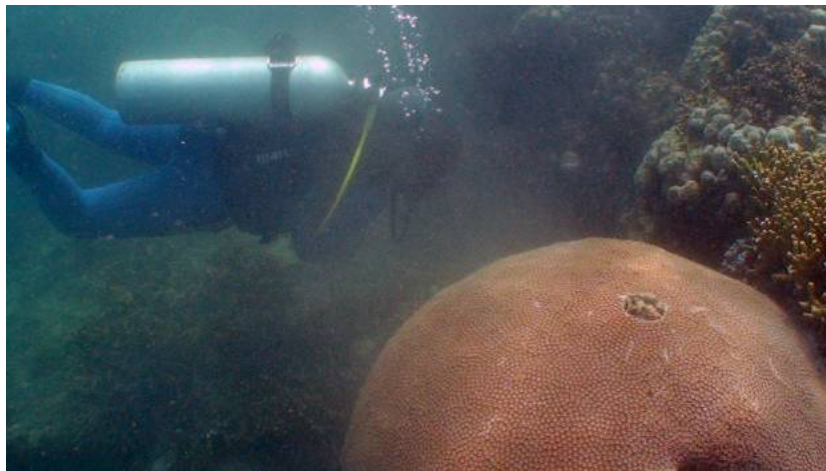


Figure 19- Live *Diploastrea heliopora* head drilled in Ngeremduu Bay, Ngatpang State, Palau, on December 2, 2008. This head is at 7 feet water depth at mid-tide and is just over 1 m high. Core ND-11 was drilled from this head.



Figure 20- Live *Diploastrea heliopora* head drilled just north of the northern Ulang Channel protected area marker buoy, Koror State, Palau on December 2, 2008. This head is at 5 m water depth at mid-tide and is about 2 m high. Cores U-12 and U-13 were drilled from this head. Notice the dead patch on the crown of the coral. U-12 was drilled vertically starting from this patch. U-13 was drilled starting at the top but angled in towards the center.



Figure 21- Live Diploastrea heliopora head drilled just north of the northern Ulang Channel protected area marker buoy, Koror State, Palau on December 2, 2008. This head is at 5 m water depth at mid-tide and is about 2 m high. Cores U-12 and U-13 were drilled from this head.

We finished working near the Ulang Channel entrance by 1700 and proceeded south to the German Channel.

December 3- The mission objectives have been largely met. We proceed to pack samples and gear, finalize reports and head back to port. We meet there representatives of the Bureau of Foreign Affairs and the Marine Resources Department (Palau Government), who inspect the samples and give their OK for export. We also give them a list of samples collected so the export permit can be prepared immediately.

December 4- The drill is disassembled, cleaned and packed for transport. Samples are carefully packed for export to Stanford University (USA), where they will be slabbed and distributed for analysis amongst CRP members. Transport arrangements are made.

Appendices

1) Satellite photos of study sites:

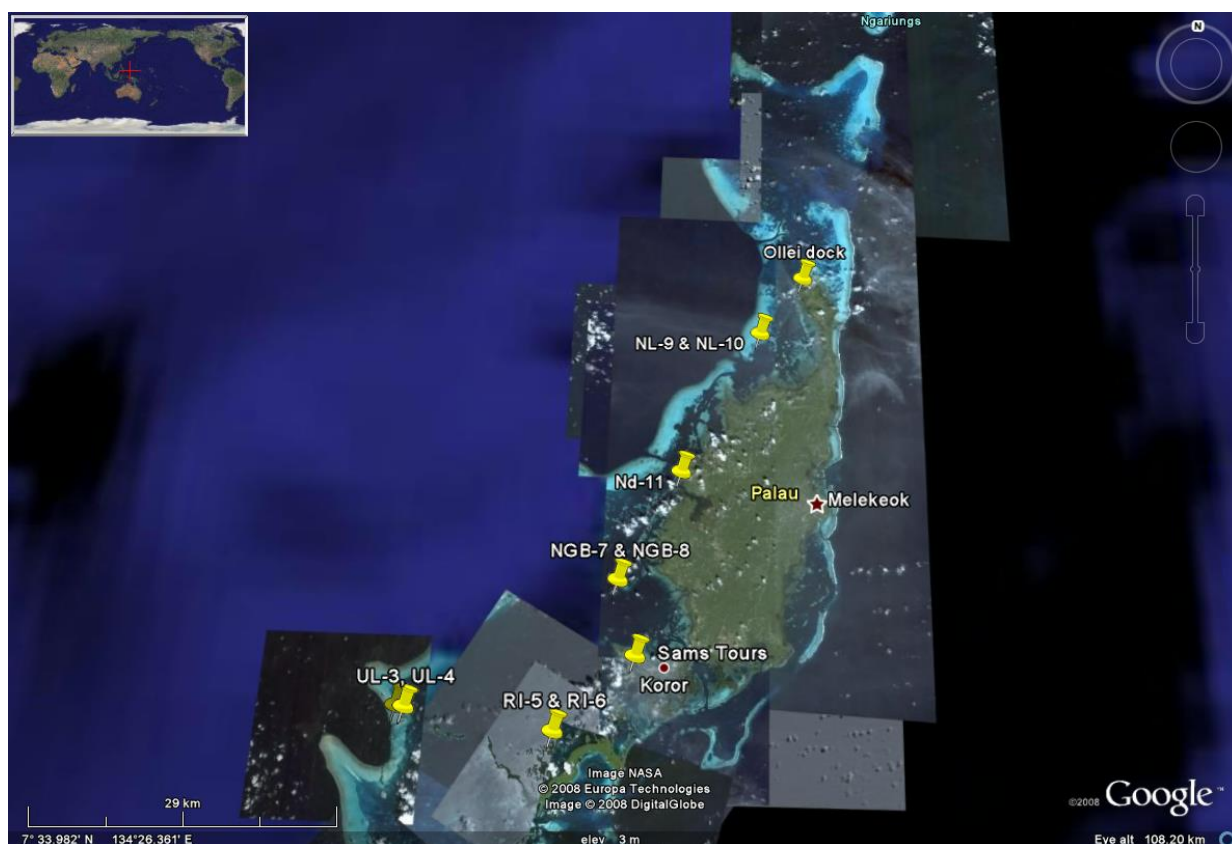


Figure 22. Core locations.



Figure 23. Ulang Channel detail.

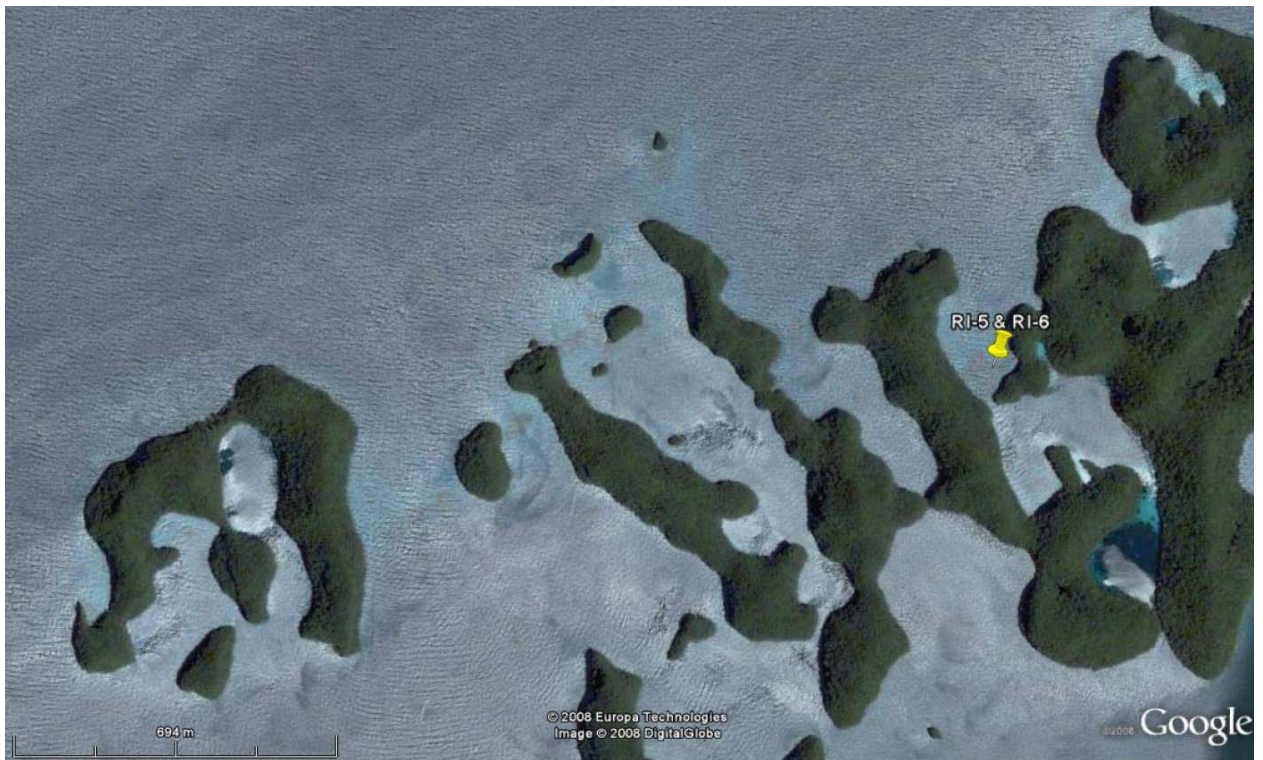


Figure 24. Rock Islands detail.

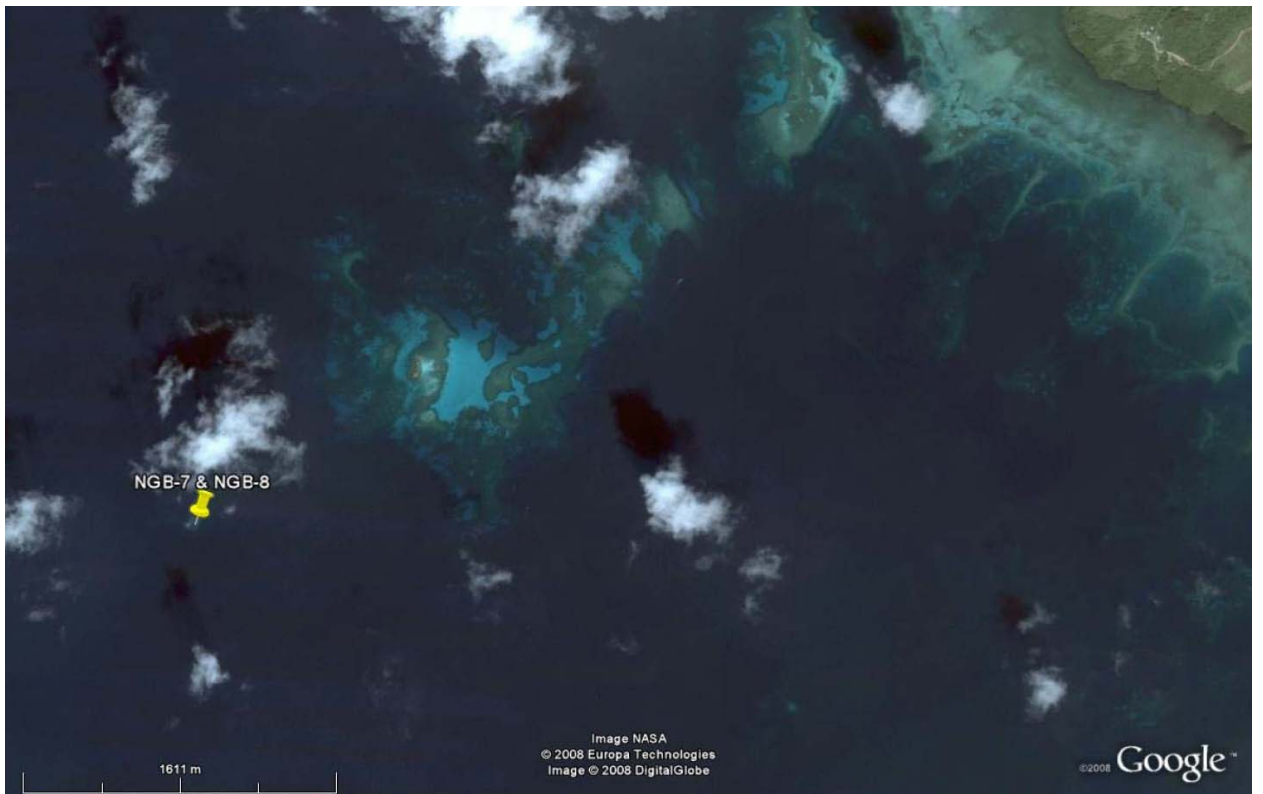


Figure 25. Ngeragabel detail.

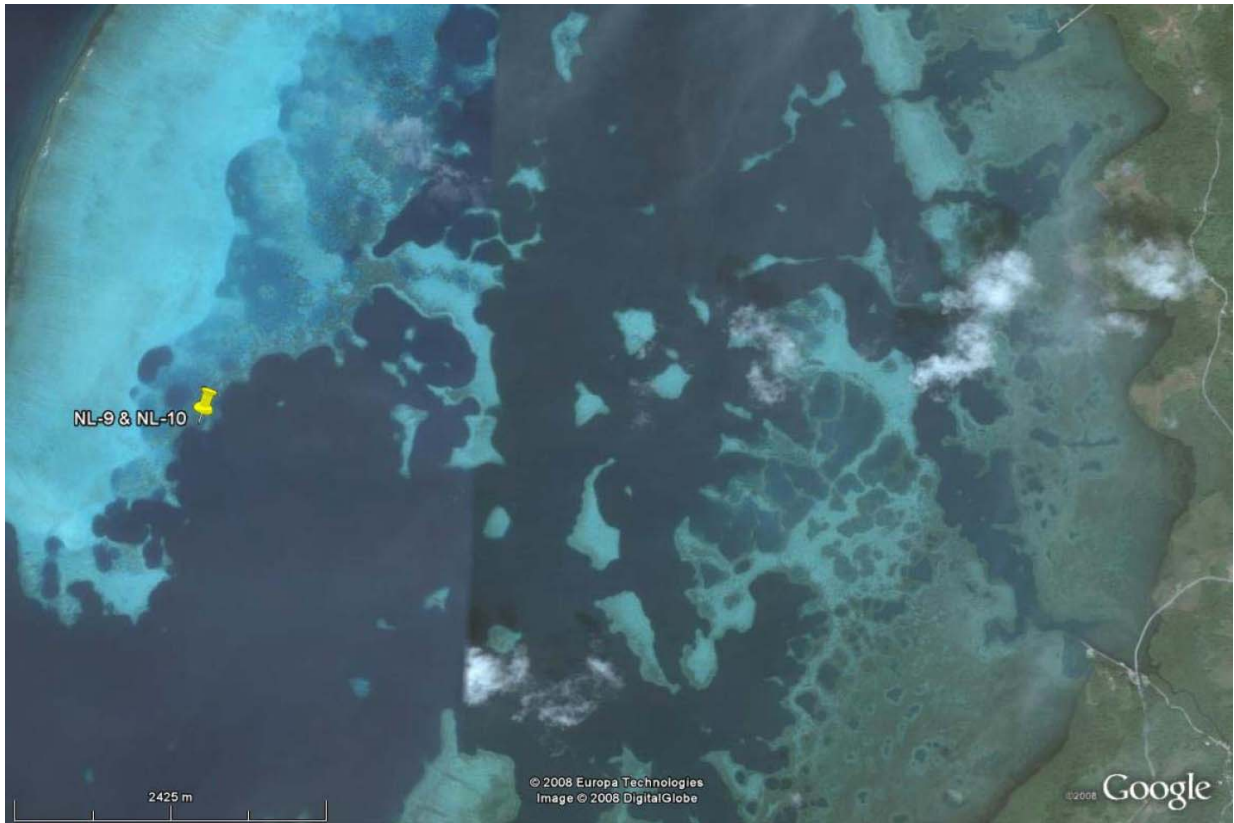


Figure 26. Ngerelang detail.

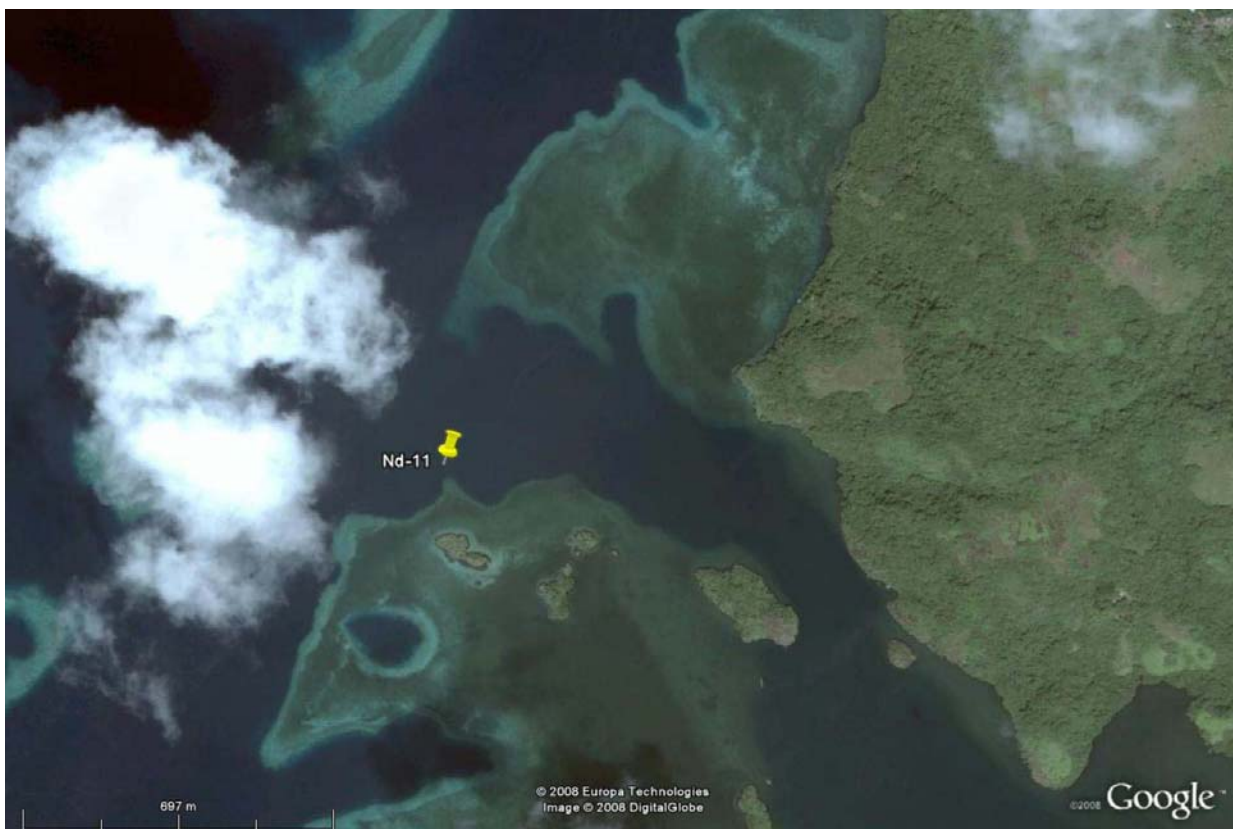


Figure 27. Ngeremduu detail.

2) Table of Cores collected.

Sample Name	Collection date	Locality	Lat.	Long.	species	live/ dead	water depth	Pieces	Length (cm)
U-1	28-Nov-08	Ulang Channel	7°17.153"N	134°15.016"E	<i>Porites lutea</i>	dead	12 m	7	188
U-2	29-Nov-08	Ulang Channel	7°17.153"N	134°15.016"E	<i>Porites lutea</i>	dead	12 m	6	272
U-3	29-Nov-08	Ulang Channel	7°17.153"N	134°15.016"E	<i>Porites lutea</i>	live	12 m	2	44
U-4	29-Nov-08	Ulang Channel	7°17.153"N	134°15.016"E	<i>Porites lutea</i>	live	12 m	1	18
RI-5	30-Nov-08	Rock Islands	7°16.248"N	134°23.024"E	<i>Porites lutea</i>	live	2 m	4	140
RI-6	30-Nov-08	Rock Islands	7°16.248"N	134°23.024"E	<i>Porites lutea</i>	live	2 m	7	258
NGB-7	1-Dec-08	Ngaragabel	7°24.386"N	134°26.115"E	<i>Porites sp.</i>	live	3 m	1	48
NGB-8	1-Dec-08	Ngaragabel	7°24.386"N	134°26.115"E	<i>Porites sp.</i>	live	3 m	2	101
NL-9	1-Dec-08	Ngeralang	7°39.413"N	134°33.907"E	<i>Porites sp.</i>	live	3 m	3	151
NL-10	1-Dec-08	Ngeralang	7°39.413"N	134°33.907"E	<i>D. heliopora</i>	live	4 m	1	60
ND-11	2-Dec-08	Ngeremduu Bay	7°30.689"N	134°29.447"E	<i>D. heliopora</i>	live	3 m	2	95
U-12	2-Dec-08	Ulang Channel	7°17.186"N	134°14.403"E	<i>D. heliopora</i>	dead	5 m	4	134
U-13	2-Dec-08	Ulang Channel	7°17.186"N	134°14.403"E	<i>D. heliopora</i>	live	5 m	2	65