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PROGRESS REPORT FOR AINGRA09006

PROJECT TITLE	Understanding coldwater coral ecosystems on the Great Barrier Reef margin	
INVESTIGATOR(S)		**Institution and Department**
Chief Investigator	**Dr Robin Beaman**	School of Earth and Environmental Sciences, James Cook University
Other Investigators	Dr Geraldine Jacobson, ANSTO Dr Jody Webster, University of Sydney Dr Alex Thomas, Oxford University	
Students	None	
ANSTO Investigators	Dr Geraldine Jacobsen	
Specialist Committee	A	

SCIENTIFIC OBJECTIVES

In 2007, we mapped the spectacular submarine landscape on the Great Barrier Reef margin. This included a completely new coldwater coral habitat in the depths of the Queensland Trough. Coldwater coral habitats are important globally as hotspots of biodiversity on the deep seabed, but their ecology is poorly understood and the corals are vulnerable to damage. The project will study the origins and biodiversity of the coldwater corals, and to understand the role of the landscape in defining the habitat boundaries. ^{14}C AMS ages of the biogenic and non-biogenic carbonate samples will be a major contribution to the overall aims of the project.

PROGRESS REPORT and RESEARCH OUTCOMES

(In addition to a discussion of your research results please indicate the value of any other funding generated by AINSE support for this project and the resulting benefits, if any, to the Australian community):

The Gloria Knolls. We investigated a cluster of eight knolls up to two km long and over 100 m high in depths of about 1200 m in the Queensland Trough that we called the Gloria Knolls (Figure 1; Webster et al., 2008). A rock dredge sample from the largest knoll in ~1170 m recovered evidence of a coldwater coral community, comprising live octocorals, dead scleractinian corals, bamboo corals, barnacles, gastropods, pteropods and hard nodules within a matrix of muddy sediment. This discovery is highly significant as little is known of the ecosystem functioning of coldwater corals or even their distribution in Australian marine waters (Hobday et al., 2006).

Age of the community. A key scientific question is how old is the coldwater coral community on the Gloria Knolls? Other studies have found coldwater coral reefs to be slow growing and developed over long periods of time. For example, fossil corals from similar knolls in the North Atlantic were dated to at least 4550 years, and due to the slow growth rate (~1.1 mm/year) it takes thousands of years for a reef to build 10 to 30 m in thickness (Hall-Spencer et al., 2002). Therefore, a hypothesis is that the maximum age of the coldwater coral community on the knolls is thousands of years old, and that the surficial fossil samples range from Holocene to the present.

^{14}C AMS ages. 12 fossil samples were analysed for ^{14}C AMS ages, in addition to a single live octocoral to explore if any reservoir age was noticeable. The carbonate cement of a non-biogenic hard nodule was also analysed to establish an age of lithification. Table 1 records the 14 conventional radiocarbon ages analysed by ANSTO (Fink et al., 2004). Samples with radiocarbon ages <22 ^{14}C ka were converted to calibrated ages (ka) using CALIB software (Stuvier and Reimer, 1993) while three samples >22 ^{14}C ka were unable to be calibrated using this method. The resulting age spread showed a modern age for the live octocoral with no reservoir effect present. The ages of the biogenic fossil samples ranged from 1.89 ka to 44.86 ^{14}C ka. The lithified nodule showed an age of 44.78 ^{14}C ka.

Comparison with sea-level curve. When the age results are compared against the eustatic sea-level curve up to marine isotope stage 5 (Figure 2; Lambeck and Chappell, 2001), the majority of the biogenic fossil ages cluster within MIS1 or the Holocene (1.89 ka to 9.25 ka). These included two barnacle plates, a gastropod, a bamboo coral, a (pelagic) pteropod, two known species of scleractinian coral, and two scleractinian corals cemented to nodules. Two older biogenic sample ages from a bamboo coral and a gastropod, lie between MIS2 and MIS3 (22.27 ka and 26.83 ^{14}C ka). Near the upper limit of the ^{14}C age technique, the lithified nodule and a scleractinian coral show ages at MIS3 (44.78 ^{14}C ka and 44.86 ^{14}C ka).

Clustering of ages? The apparent clustering of ages could indicate periods of favourable environmental or biological conditions (e.g. increased food supply, aragonite saturation levels, larval settlement, enhanced substrate etc.) leading to peaks of biogenic material preserved in the sediment. This certainly appears to be the case for the majority of the samples, i.e. a peak of community growth (then death) within the Holocene up to the present. For the older samples, peaks of biogenic growth are harder to prove as it may simply be the result of sampling bias. Only a more extensive sampling program (more dredges and long cores) at the Gloria Knolls would prove this. The age results do confirm our original hypothesis but significantly extend the age of the coldwater coral community back through MIS2 (Last Glacial Maximum) to MIS3.

Age of the knolls. Of note is that sediment analyses proves that the lithified nodule is authogenic, i.e. formed *in situ* from the muddy matrix. This means that the unlithified muddy matrix prior to calcification is at least as old as 44.78 ^{14}C ka. Given that the rock dredge only sampled about 0.5 m into the seabed surface and that the sub-bottom profiler records a cap of 6 to 14 m thick semi-opaque parallel reflectors over the knolls (Beaman and Webster, 2008), then the extent of time since sediment accumulation began on the knolls must extend much further back into the past. In turn, the catastrophic landslide event on the GBR margin that produced the original debris blocks, resulting in the Gloria Knolls, must be older still. All evidence points to this landslide being an ancient event (Beaman and Webster, 2008).

Future research. All biogenic fossil samples have been sent to Oxford University for paired U-Th age dating. The Gloria Knolls coldwater coral community is growing in ~1200 m and not in surface mixed water. The near-seabed Subantarctic Mode Water is carrying older carbon and so is not the standard atmospheric global reservoir age for marine samples (400 years in CALIB software). The paired U-Th ages will help generate a local reservoir age dataset that will allow calibration fine-tuning of the ^{14}C AMS ages. In addition, the two bamboo corals have been sent to CSIRO Marine and Atmospheric Research laboratories for Mg/Ca ratio analyses. These results will help establish proxies for ocean temperatures during their lives at the Gloria Knolls site.

Value to Australian community. The discovery of the Gloria Knolls and their associated coldwater corals on the GBR margin has significance to marine managers charged with future planning to prevent damage to these sensitive coral ecosystems. Like old growth temperate rainforests on land, coldwater coral ecosystems take a long time to develop and have intrinsic value for the complex habitats they provide to fish and other benthic marine life on the surrounding flat muddy seafloor. The value of the AINSE support and other funding sources (see Acknowledgments) for this project provides the Australian community with knowledge about the origin and longevity of this vulnerable marine ecosystem, emphasising the importance of protecting the area from any damaging human influences.

Conclusion. The results of the ^{14}C AMS analyses show:

- The coldwater coral community on the Gloria Knolls is a long-lived and persistent community with ages ranging back to about 45 ^{14}C ka.
- The Holocene appears to have been a period of prolific biogenic growth for a diverse range of benthic species in the coldwater coral community.
- The results put a minimum age of about 44 ^{14}C ka on the surficial sediment matrix but points to a much older age for the commencement of sediment build-up on top of the knolls.
- This work provides Australian marine managers with knowledge about the origin and longevity of this vulnerable marine ecosystem.

DATA (Please summarise the data collected within this Award. You may use tables, graphs or diagrams)

Figure 1. Diagram of the Great Barrier Reef margin and Gloria Knolls. The knolls appear to be the remains of large debris flow blocks from a large undersea landslide on the continental slope, and are now largely buried by hemipelagic sediments in the Queensland Trough. Strong near-seabed currents flow northerly over the knolls. The rock dredge sampled a coldwater coral community across the top of one of the knolls. EAC is the East Australian Current. SMW is Subantarctic Mode Water.

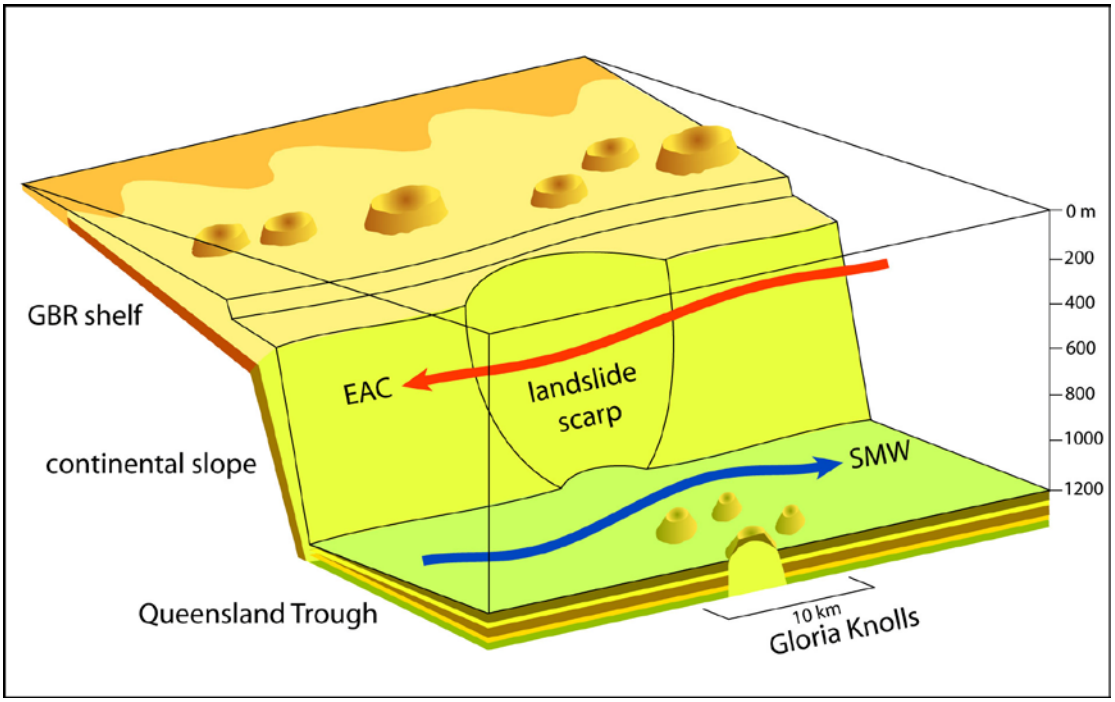
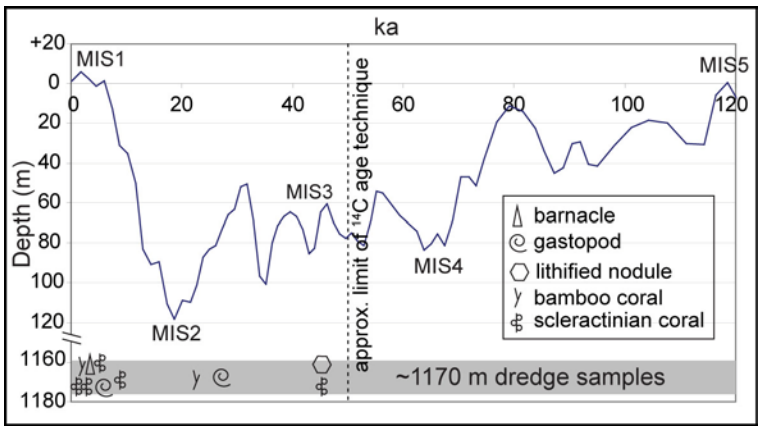


Table 1. ^{14}C AMS ages from live and fossil samples recovered from the Gloria Knolls. Calibrated ages were generated using CALIB Ver. 5.0.1 software (Stuvier and Reimer, 1993) with the Marine04 calibration dataset. Radiocarbon ages >22 ^{14}C ka were not calibrated due the limitations of the program.

ANSTO lab code	Sample code	Sample name	Radiocarbon age (^{14}C ka)	1σ error (^{14}C ka)	Calibrated age (ka)	2σ range (ka)
OZL545	live gorgonian	*Viminella* sp.	modern			
OZL546	bamboo coral 1	unknown sp.	19.10	0.18	22.27	22.09-22.44
OZL547	scleractinian coral 1	unknown sp.	44.86	0.85		
OZL548	scleractinian coral 2	*Enallopsammia rostrata*	2.56	0.07	2.23	2.13-2.32
OZL549	scleractinian coral 3	*Madrepora oculata*	2.28	0.07	1.89	1.80-1.99
OZL550	gastropod 1	*Calliotropis pagodiformis*	26.83	0.16		
OZL551	gastropod 2	*Pontiothauma* sp.	5.40	0.10	5.77	5.64-5.89
OZL552	coral on semi-lith. nodule	unknown sp.	5.08	0.08	5.43	5.31-5.55
OZL553	coral on lith. nodule	unknown sp.	8.59	0.10	9.25	9.09-9.40
OZL554	lithified nodule		44.78	0.64		
OZL555	barnacle 1	*Scillaelepas fosteri*	3.25	0.07	3.07	2.95-3.20
OZL556	barnacle 2	*Scillaelepas fosteri*	2.54	0.07	2.21	2.11-2.31
OZL557	pteropod	*Cavolinia tridentata*	3.66	0.10	3.56	3.42-3.69
OZL558	bamboo coral 2	unknown sp.	2.78	0.07	2.52	2.37-2.66

Figure 2. Graph of symbols representing fossil and nodule sample ^{14}C AMS ages against the eustatic sea-level curve up to the last interglacial at MIS5 (Lambeck and Chappell, 2001). The majority of samples cluster within the Holocene, however, four samples also show ages older than marine isotope stage 2 (MIS2) up to the approximate limit of the ^{14}C age technique at MIS3.



Signature of Investigator preparing the report for **After signing this report please fax this page with your signature for our files**	**Proj: AINGRA09006** **Date:**
R. Beaman	16 Sep 2009

PUBLICATIONS / REPORTS arising as a result of your work.

Please provide references in the following format Relevant AINSE Grant no(s); paper; Journal, Conference Proceedings or Book Title; Volume, ISSN/ISBN no., or Book/Publisher; Page numbers. Put an (s) to indicate that AINSE support was acknowledged and a (c) to indicate that AINSE has been provided with a copy.

AINGRA09006: Conference Proceedings (s) (c): Beaman, R.J., Webster, J.M., 2008. Gloria Knolls: A new coldwater coral habitat on the Great Barrier Reef margin, Australia. In: H. Neil and D. Tracey (Editors), 4th International Symposium on Deep-Sea Corals, 1-5 December 2008. National Institute of Water and Atmospheric Research, Wellington, New Zealand, pp. 248.

AINGRA09006: Journal (s): Beaman, R.J., Webster, J.M., Thomas, A. and Jacobsen, G., in prep. Continental slope mass wastage origin for coldwater coral habitats on the Great Barrier Reef margin. Marine Geology.

PhD STUDENTS For each student involved with the project, please indicate the date or anticipated date of conferment of a PhD or other award, and give the title of the thesis.

There are no PhD students involved with this project.

Acknowledgments

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References

Beaman, R.J., Webster, J.M., 2008. Gloria Knolls: A new coldwater coral habitat on the Great Barrier Reef margin, Australia. In: H. Neil and D. Tracey (Editors), 4th International Symposium on Deep-Sea Corals, 1-5 December 2008. National Institute of Water and Atmospheric Research, Wellington, New Zealand, pp. 248.

Fink, D., Hotchkis, M., Hua, Q., Jacobsen, G., Smith, A.M., Zoppi, U., Child, D., Mifsud, C., van der Gaast, H., Williams, A., Williams, M. (2004), The ANTARES AMS facility at ANSTO, Nuclear Instruments and Methods in Physics Research B, 223-224: 109-115, doi: 10.1016/j.nimb.2004.04.025.

Hall-Spencer, J., Allain, V., Fossa, J.H. (2002), Trawling damage to Northeast Atlantic ancient coral reefs, Proceedings of the Royal Society of London Series B, 269: 507-511, doi: 10.1098/rspb.2001.1910.

Hobday, A.J., Okey, T.A., Poloczanska, E.S., Kunz, T.J., Richardson, A.J., 2006. Impacts of climate change on Australian marine life: Part C. Literature Review. Report to the Australian Greenhouse Office, CSIRO Marine and Atmospheric Research, Canberra, Australia.

Lambeck, K., Chappell, J., 2001. Sea level change through the last glacial cycle. Science, 292: 679-685.

Stuvier, M., Reimer, P.J., 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. Radiocarbon, 35(1): 215-230.

Webster, J.M., Beaman, R.J., Bridge, T., Davies, P.J., Byrne, M., Williams, S., Manning, P., Pizarro, O., Thornborough, K., Woolsey, K., Thomas, A., Tudhope, S., 2008. From corals to canyons: The Great Barrier Reef margin. EOS, 89(24): 217-218.