Commonwealth Environment Research Facilities
Marine and Tropical Sciences Research Facility

Impacts and Achievements of the MTSRF

Copy of abstract and presentation given at the 2010 Annual Conference of the Marine and Tropical Sciences Research Facility (MTSRF)
http://www.rrrc.org.au/news/2010_conference.html

Showcasing the Australian Government's investment in the MTSRF for improved sustainability of the North Queensland region, and Australia

18-20 May 2010
Pullman Reef Hotel & Casino
Cairns, North Queensland

Reef & Rainforest RESEARCH CENTRE

Australian Government
Department of the Environment, Water, Heritage and the Arts

Abstract

MTSRF Project Number 1.1.4

U-series dating of historical changes in GBR coral communities – Progress report and future plan

Jian-xin Zhao[1], Tara Clark[1,3], George Roff[2], Kefu Yu[1], Terry Done[4], Laurence McCook[5], John Pandolfi [2,3]
[1]Radio Isotope Facility, University of Queensland; [2]ARC Centre of Excellence for Coral Reef Studies, University of Queensland; [3]School of Earth Sciences, University of Queensland; [4]Australian Institute of Marine Science, Townsville QLD4810; Great Barrier Reef Marine Park Authority, Townsville, QLD 4810

Trajectories of decline have been observed in coral reefs throughout the Caribbean and Indo-Pacific region from the present day, attributable to the synergistic effects of human-induced disturbances. Whilst direct and indirect evidence suggests that inshore reefs from the Great Barrier Reef (GBR) are showing signs of regional decline following European settlement in the mid 18th century, it has proven difficult to ascertain the link between anthropogenic disturbance and coral degradation on a regional scale. We present a synthesis of research from the past four years focusing on 1) historical mortality in coral communities and massive *Porites* corals in the Palm Islands region (central Inshore GBR) and adjacent catchments in the southern GBR (Mackay region) and from far northern GBR (with over 200 U/Th dates obtained so far), and 2) historical patterns of storms on the offshore GBR (One Tree and Heron Reefs) (with over 120 dates obtained). Our research revealed shifts in coral community structure and indicates a loss of previously dominant *Acropora* corals in the early 20th century due to synergistic impacts of sediment flux and climatic factors. Analysis of uplifted reef blocks from the offshore GBR reveals several relatively stormy periods throughout the 19th and 20th centuries. Overall, our results show that U-series dating and palaeoecological approaches can provide unique insights into a broad range of critical questions on the GBR. Our work so far shows that the key challenges of our project lie in the analytical difficulty in dating extremely young corals and the bottleneck of our existing dating facility (the TIMS). Both problems have now been resolved and a new dating facility with 5-10 times higher throughput and sensitivity (MC-ICP-MS) has now become available. With this in mind, we have developed new plans to consolidate and expand our research under the flagship of a possible MTSRF-II.

U-series dating of historical changes in GBR coral communities – Progress report on MTSRF Project 1.1.4 and future plan

Jian-xin Zhao[1], Tara Clark[1,2], George Roff[3], Kefu Yu[1], Claire Reymond[3], Terry Done[4], Laurence McCook[5], John Pandolfi [2,3]

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THE UNIVERSITY OF QUEENSLAND

Reef & Rainforest RESEARCH CENTRE

Australian Government
Great Barrier Reef Marine Park Authority

Recent climate change and European settlement have had severe impact on GBR coral community. As a result, many inshore reefs have experienced historic bleaching, mortality and degradation since European settlement.

However, it is unknown exactly when mortality events occurred and what status of community structure is considered as “pristine”. The timing of mortality and better understanding of past pristine status is crucial for assessing current status and linking reef degradation to stressors for better targeted management strategies.

This project aims to use high-precision U-series dating combined with field survey and ecological analysis to address such fundamental questions.

Outline

- Introduction to MTSRF Project 1.1.4;
- Introduction to U-series dating technique;
- Research Highlights on dating:
  1. method validation (see next talk by Tara Clark)
  2. surface death assemblage & back-reef sediment cores (see next talk by Laurence McCook)
  3. cyclone blocks & lagoon cores (see next talk by Kefu Yu)
- Future Plan

MTSRF Project 1.1.4 - Dating and mapping historical changes in GBR coral communities

Funding Sources:

MTSRF – total $185,000 for 4 years

Large UQ & AIMS co-investment: salary, scholarships, discount rates for lab use, shipment, matching funds from other sources

Team members: 5 staff members & 7 research students

UQ

Jian-xin Zhao (Geochronology)
John Pandolfi (Reef Ecology)
Kefu Yu (cyclone reconstruction)
Geogre Roff (Ph.D)
Tara Clark (Ph.D)
Alberto Rodríguez-Ramírez (Ph.D)
Claire Reymond (Ph.D)
1 MSc & 1 Honour's

AIMS

Terry Done

GBRMPA

Laurence McCook

More people involved in assisting fieldwork and sample collections

MTSRF Project 1.1.4 main objectives:

- Fine-tune the U-series method for dating sediment-contaminated corals 0-200 years of age with ±1-10 yr uncertainty.
- Determine the decadal death rate of both massive and branching corals since European settlement.
- Assess coral community structure change since European settlement.
- Correlate rates of coral mortality with major human developmental and recent climate events (e.g. El Niño, Pacific Decadal Oscillations).
- Reconstruct coral mortality rates and community change over the past millennium leading up to European settlement using short sediment cores from back reef environment.
- Reconstruct cyclone history and frequency over the past millennium through precise dating of transported reef blocks and lagoon sediment cores.
- Distinguish the impact of human developmental events and anthropogenically-induced global warming from natural variability.

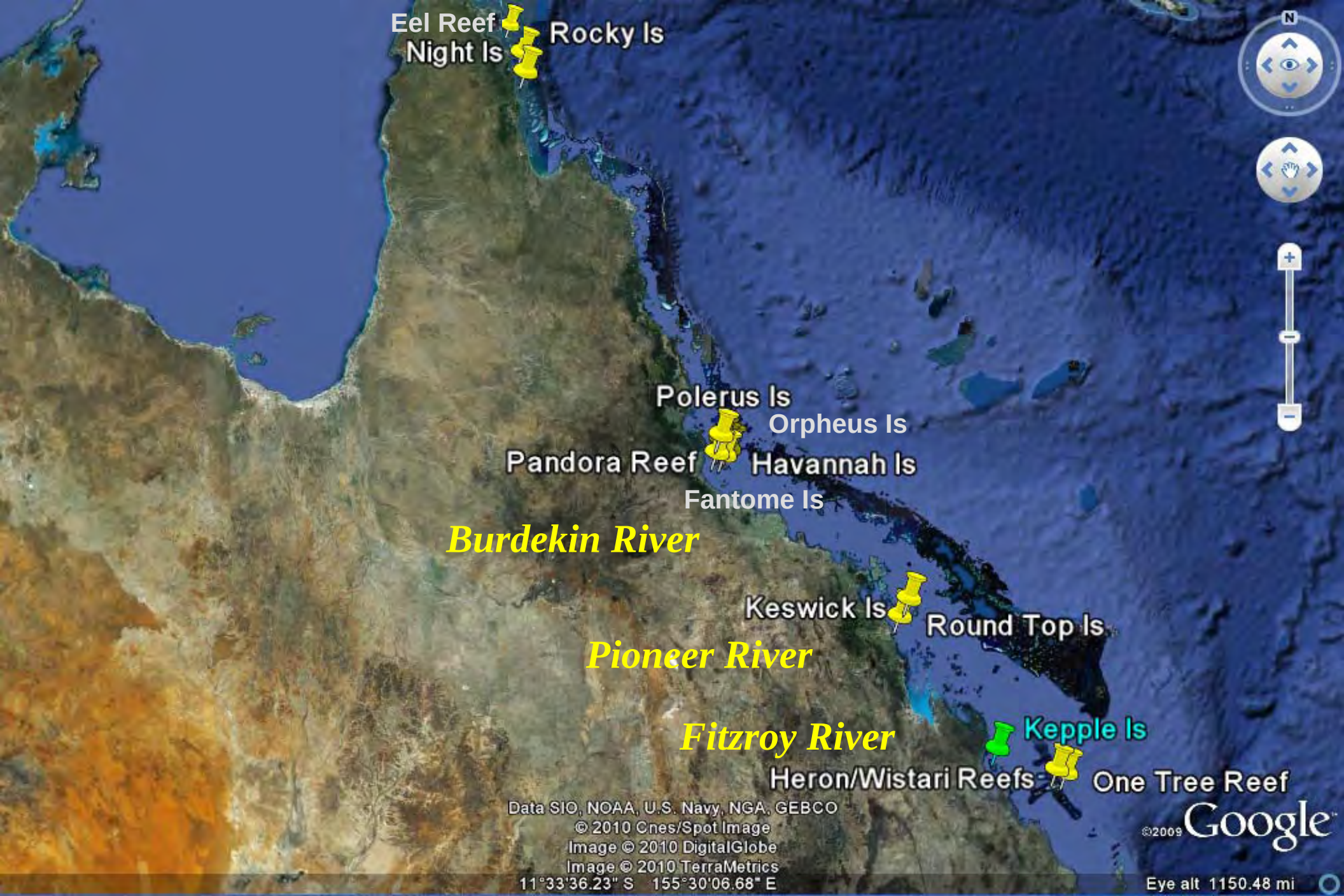
MTSRF Project 1.1.4 - Dating and mapping historical changes in GBR coral communities

Output:

- Surveyed 10 inshore reefs, 3 outer reefs and AIMS core library
- Underwater videos
- Collected surface death assemblages from southern, central & far-north GBR
- 70 back-reef sediment cores of 2-5 m long each from central GBR
- 200 cyclone uplifted coral/reef blocks from Heron, Wistari & One Tree reefs
- 10 lagoon sediment cores of 2-5 m long each from One Tree Reef
- 70 dead *Porites* short cores from central GBR
- Live *Porites* cores from S/C/N GBR
- 320 U/Th dates so far, ecological analyses, other geochemical analyses

Outcome:

- Published 3 journal articles and a number of conference abstracts
- Submitted 1 Ph.D thesis
- 4 manuscripts ready for submission (one targeting Nature or Nature Geosci)
- More Ph.D theses and papers, together with database/reports on the way


Eel Reef
Night Is
Rocky Is
Polerus Is
Orpheus Is
Pandora Reef
Havannah Is
Fantome Is
Burdekin River
Keswick Is
Round Top Is
Pioneer River
Fitzroy River
Kepple Is
Heron/Wistari Reefs
One Tree Reef
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Cnes/Spot Image
Image © 2010 DigitalGlobe
Image © 2010 TerraMetrics
11°33'36.23" S 155°30'06.68" E
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Branching coral rubbles

Branching coral rubbles

Dead massive *Porites*

Fieldwork to Palm Is 8/2009


Brian Beck
Sept 2009
Claire Redmond
Poshni Narayan
Kyle Gomez
ALBERTO RODRIGUEZ = BETO
I eat everything
I'm a geologist

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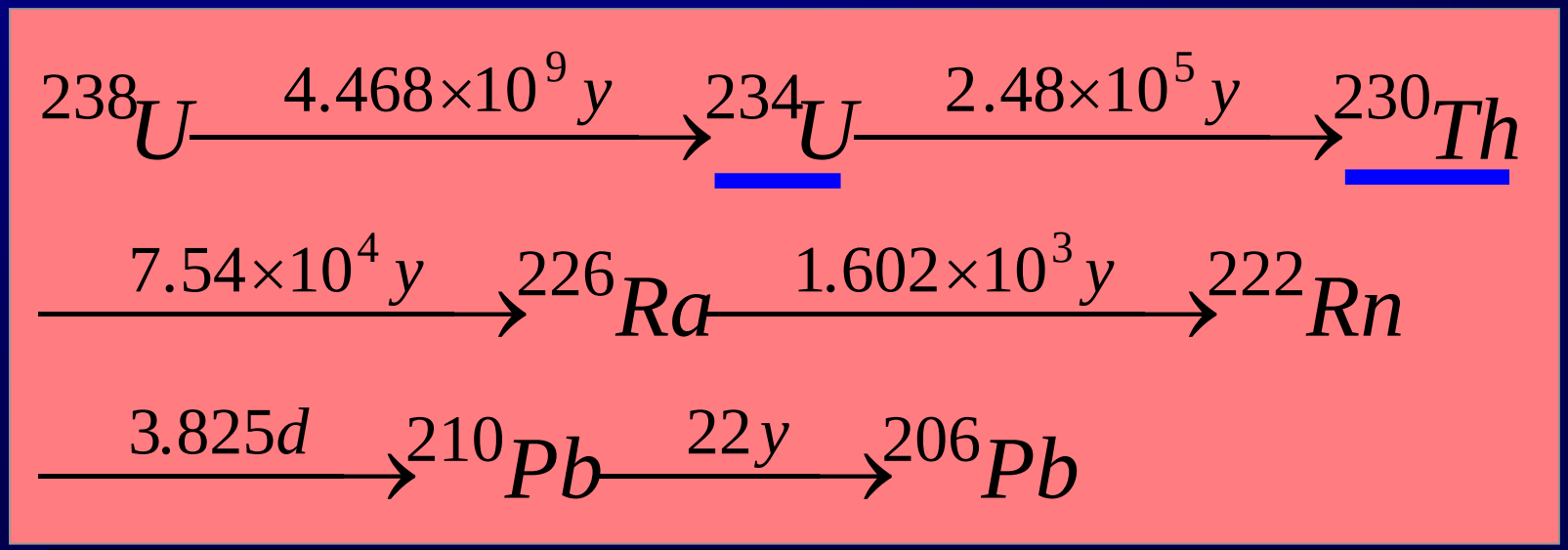
U-series dating (also called U/Th dating) involves precise measurement of low-abundance, short-lived nuclides (e.g. ^{234}U and ^{230}Th) in the decay chain



Application range 0 – 500,000 years

Many carbonate materials are suitable for U-series dating, examples are:

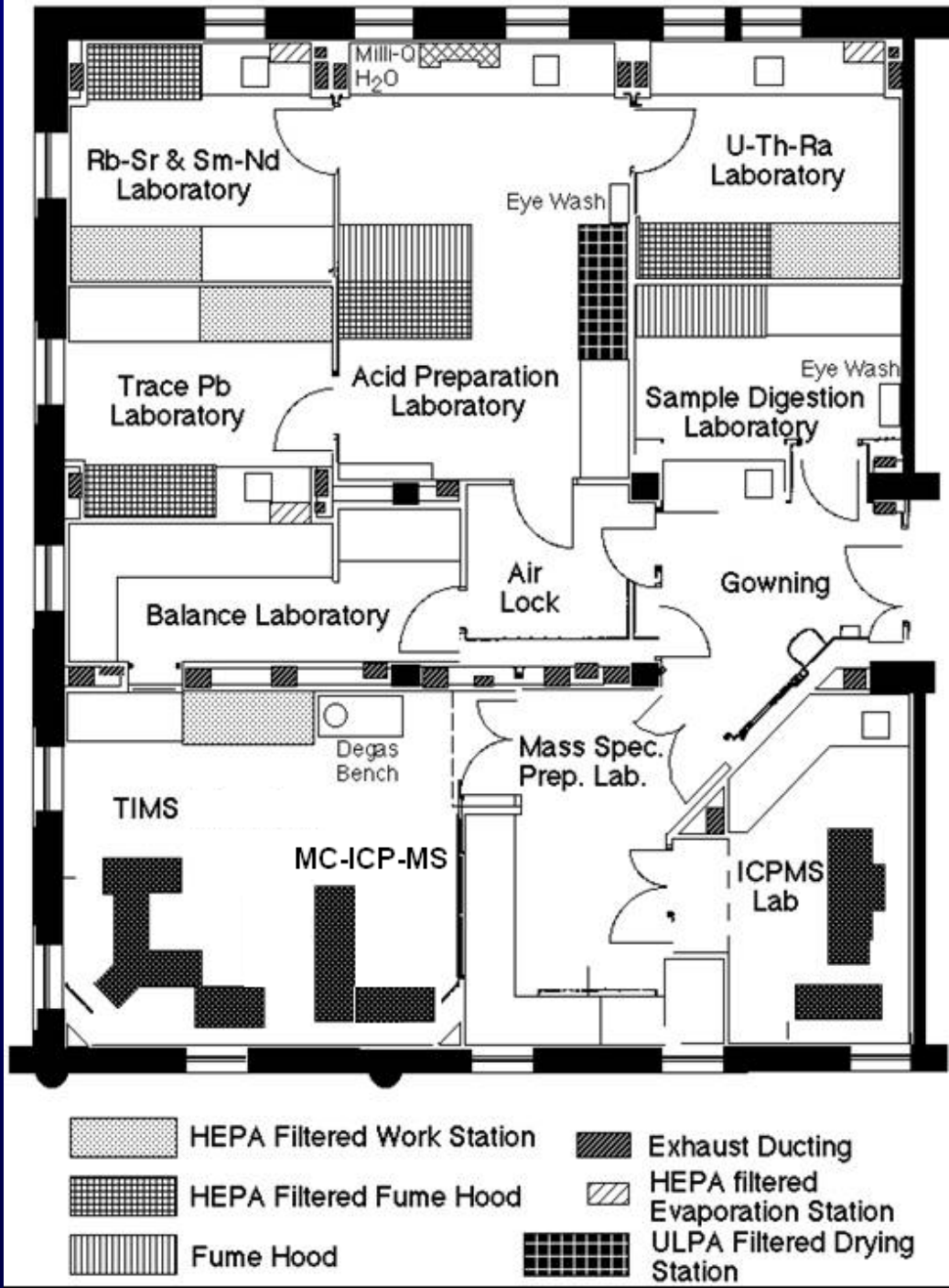
- corals
- Speleothems
- Calcite veins
- carbonate-rich lake sediments
- marine sediments

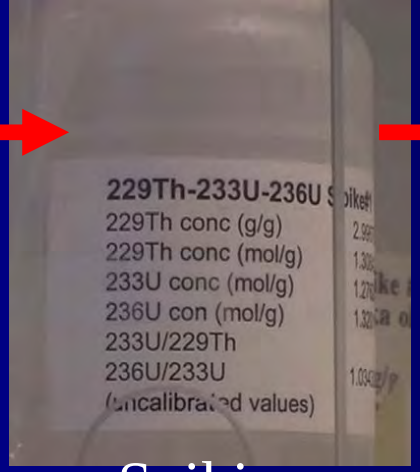
$$\frac{^{230}\mathrm{Th}}{^{238}\mathrm{U}} = 1 + \left(\left(\frac{^{232}\mathrm{Th}}{^{238}\mathrm{U}}\right)\left(\frac{^{230}\mathrm{Th}}{^{232}\mathrm{Th}}\right)_i - 1\right)\mathrm{e}^{-\lambda_{230}t} + \frac{\delta^{234}\mathrm{U}_m}{1000}\left(\frac{\lambda_{230}}{\lambda_{230}-\lambda_{234}}\right)\left(1-\mathrm{e}^{(\lambda_{234}-\lambda_{230})}\right)$$

U-series dating at UQ

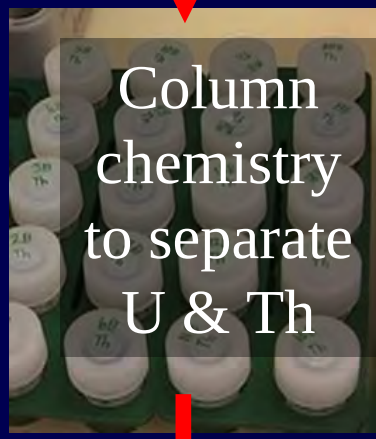
- Ultra-clean laboratory – air quality, T & H fully-controlled
- Ultra-clean reagents
- Sector 54 TIMS – 17 years old
- **Average throughput – 3 to 5 U-series dates/day.**
- **In April 2010, a new ARC LIEF-funded MC-ICP-MS was installed, enabling us to date 20-40 samples per day!**


NU-Plasma
MC-ICP-MS





Sample vetting/weighing → Spiking → Digestion



Column chemistry to separate U & Th

Loading onto Re ribbon

TIMS Measurement

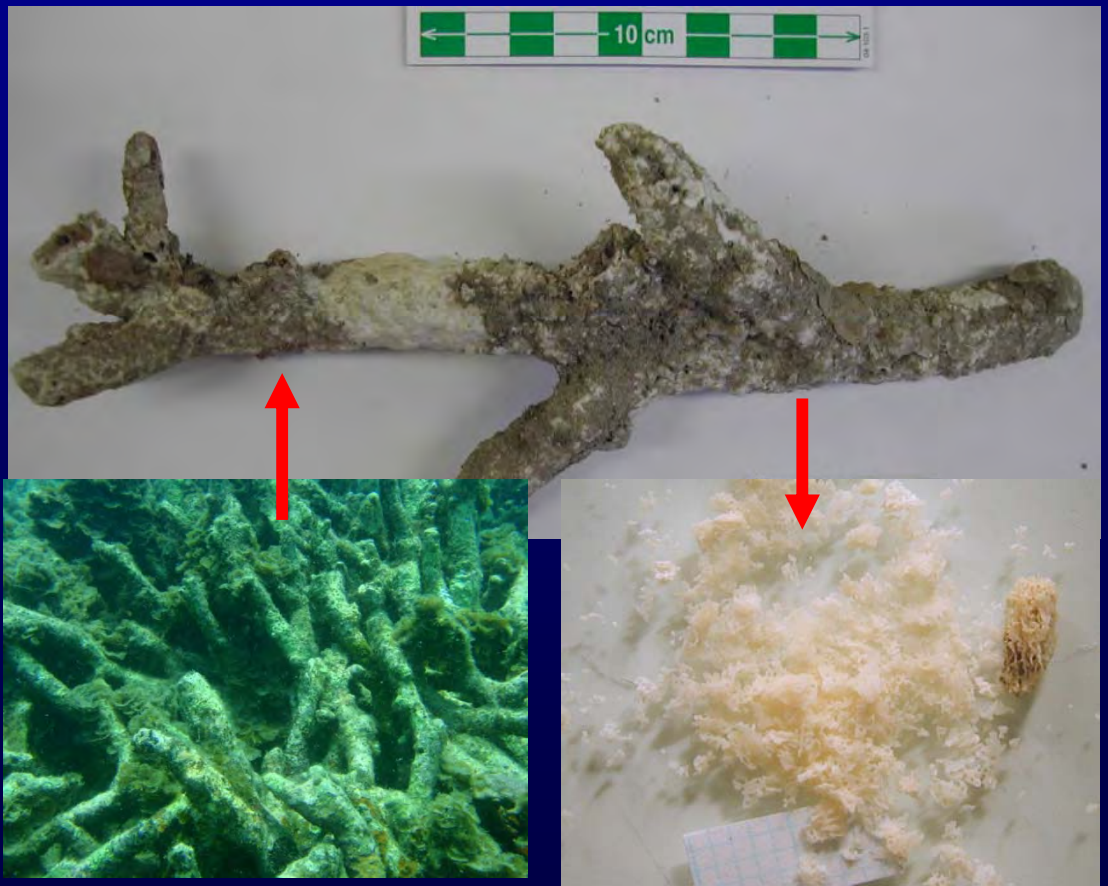
U/TH AGE PRODUCTION LINE

Challenges in dating sediment-contaminated coral rubbles of last 200 years:

- Extremely low radiogenic ^{230}Th – need specially controlled environment & long measurement time
- Most GBR coral death assemblage contaminated by sediment, leading to high proportion non-radiogenic ^{230}Th - must be corrected for, leading to large age uncertainty.
- In order to increase age precisions, $^{230}Th_{NR}$ sources must be characterized & its levels reduced (see Tara Clark's talk)
- Labour-intensive & instrument bottleneck

- So far only three laboratories in Australia have established U-series techniques for dating carbonates, only UQ Lab routinely dating extremely young corals (<200 yrs). So far, >1000 samples <500 yr old dated in our lab

Typical U/Th dates for surface death assemblages from Polerus Reef



Sample Name	^{230}Th Age (AD)
PA6A1	1949±2
PA3A1	1950±1
PA6A2	1951±2
PA7A2	1953±2
PB4B2	1984±1
PB7A1	1991±1
PB7B1	1996±5
PB4A1	1996±3
PB7B2	1997±1
PB1A1	2003±2
PC2B1	1932±3
PC2A1	1935±2
PC4A1	1936±3
PC4B2	1937±3

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Highlight 1: Spatial variability of initial $^{230}Th/^{232}Th$ in modern *Porites* from the Great Barrier Reef: Implication for U-series chronologies

Tara R. Clark, Jian-xin Zhao, Yuexing Feng, Terry Done, Stacy Jupiter4, Janice Lough3, Eric Matson3, John Pandolfi

(intended for submission to *Geochimica et Cosmichimica Acta)*

Dating method development paper reporting 43 U-Th isotope measurements of live massive *Porites* core samples of known age from Rocky Island, Eel Reef and Night Island (Far northern GBR), Pandora Reef, Havannah Island and Orpheus Island (Central GBR) and Keswick and Round Top Islands (Southern GBR)

(Next talk by Tara Clark)

Highlight 2: Palaeoecological evidence of a historical collapse of Acroporid corals on the inshore Great Barrier Reef following European settlement

George Roff , Tara R Clark, Claire Reymond, Jian-xin Zhao, Yuexing Feng, Laurence J McCook, Terry Done, John M Pandolfi
(intended for submission to *Nature or Nature Geoscience)*

Revealed for the first time shifts in coral community structure and indicates a local loss of previously dominant Acropora corals in the early 20th century due to synergistic impacts of sediment flux and climatic factors and highlights the issues around “shifting baseline syndrome” that may impact risk assessment and management strategies.

(Next talk by Laurence McCook)

Highlight 3: Stability, diversity and growth rates of inshore coral communities from the Great Barrier Reef

George Roff , Handley JC, Claire Reymond, Jian-xin Zhao, John M Pandolfi

(intended for submission to *Ecology)*

Summarize the results of over 40 sediment cores from Pandora and Havannah reefs to date, with ~120 U-series dates completed for these cores, allowing high resolution records of coral community structure at decadal – millennial resolution. The results suggest that coral communities from these inshore reefs undergo long periods of stability, followed by shifts in coral community structure to alternate states.

(Next talk by Laurence McCook)

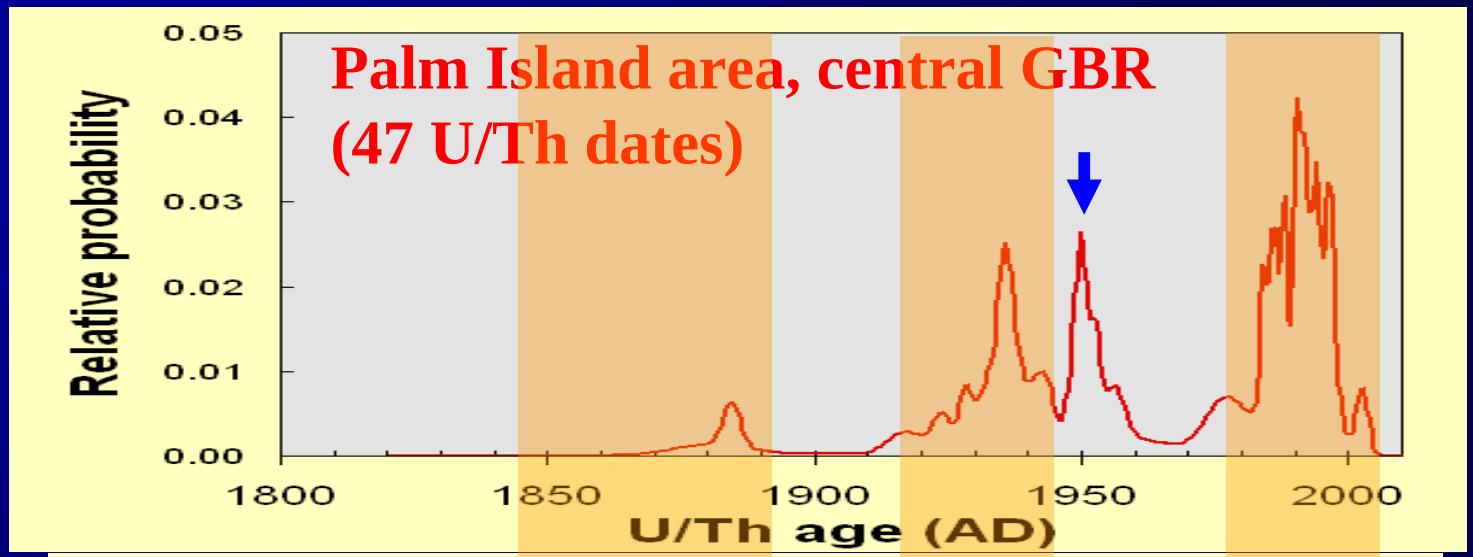
Highlight 4: Late Holocene growth rates of two inshore fringing reefs from the Palm Islands region, central Great Barrier Reef

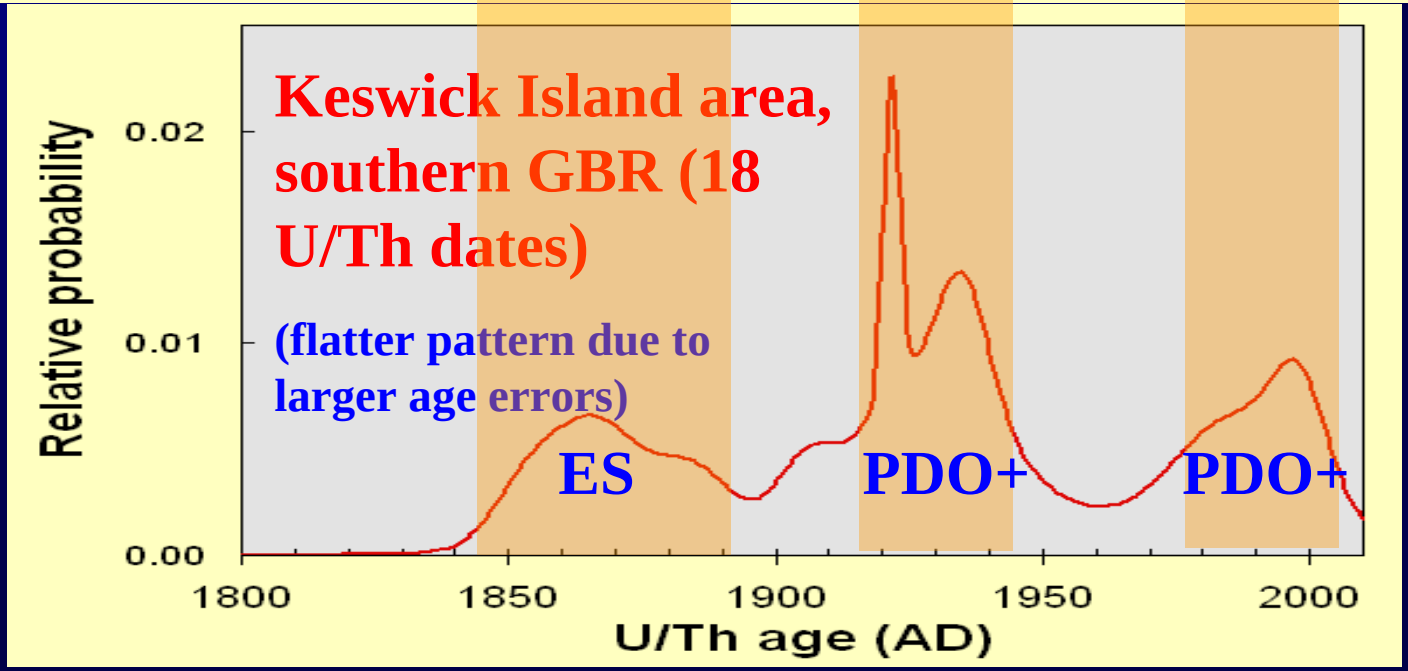
George Roff, Jian-xin Zhao, and John M. Pandolfi

(intended for submission to *Geology)*

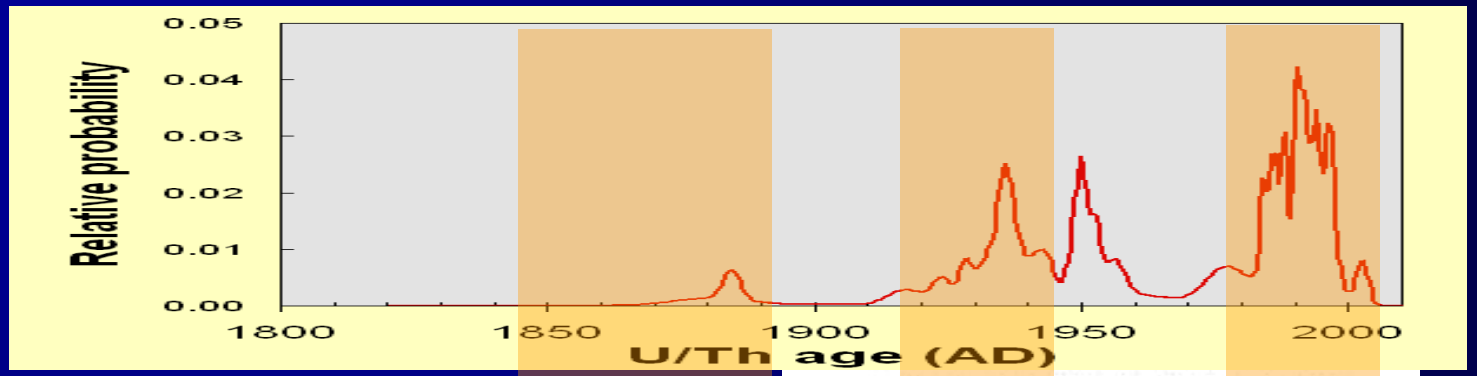
Based on high-precision U-Series chronology, this paper reconstructs a detailed late Holocene reef accretion record. The results show that reef accretion rates were highly constrained within cores with no evidence of age reversals, suggesting continuous and rapid accretion throughout the late Holocene. Comparisons to reef accretion rates from early-mid Holocene inshore GBR growth trajectories from the published literature suggests that accretion in modern reef slope environments occurs at rates equal to and exceeding those of the mid-Holocene ‘optimum’.

Highlight 5: Inter-regional comparison in coral mortality



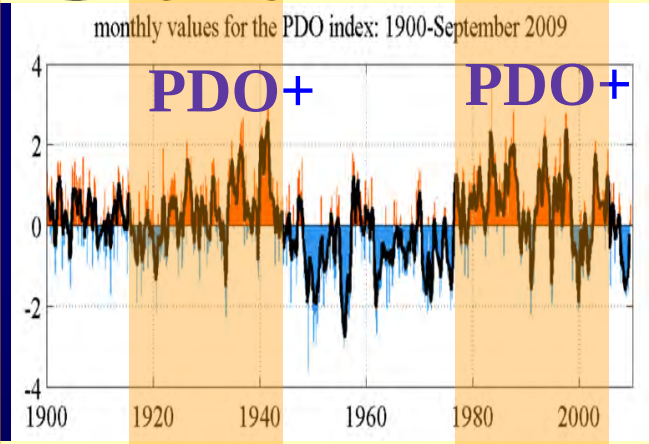


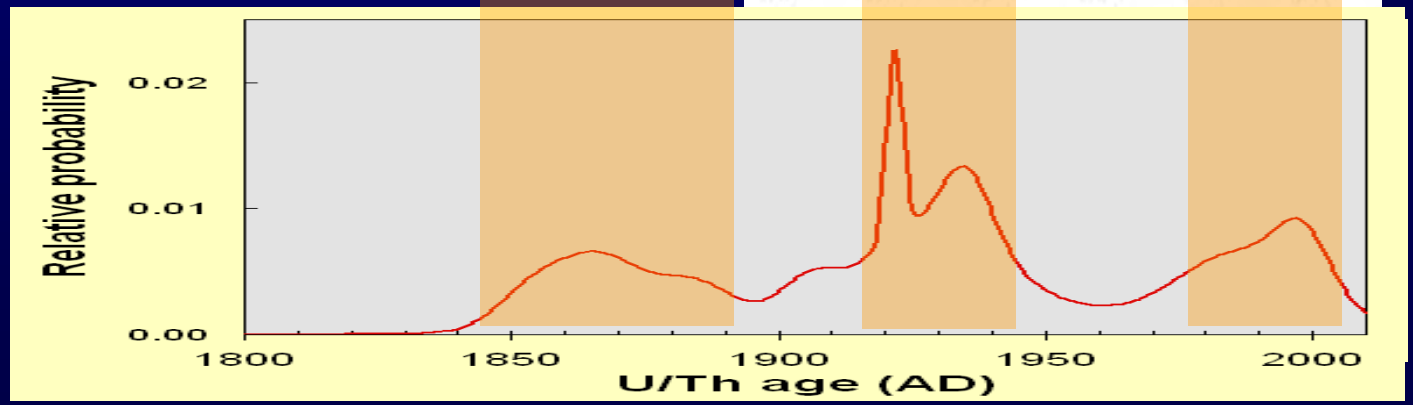
Highlight 5: Inter-regional comparison in coral mortality



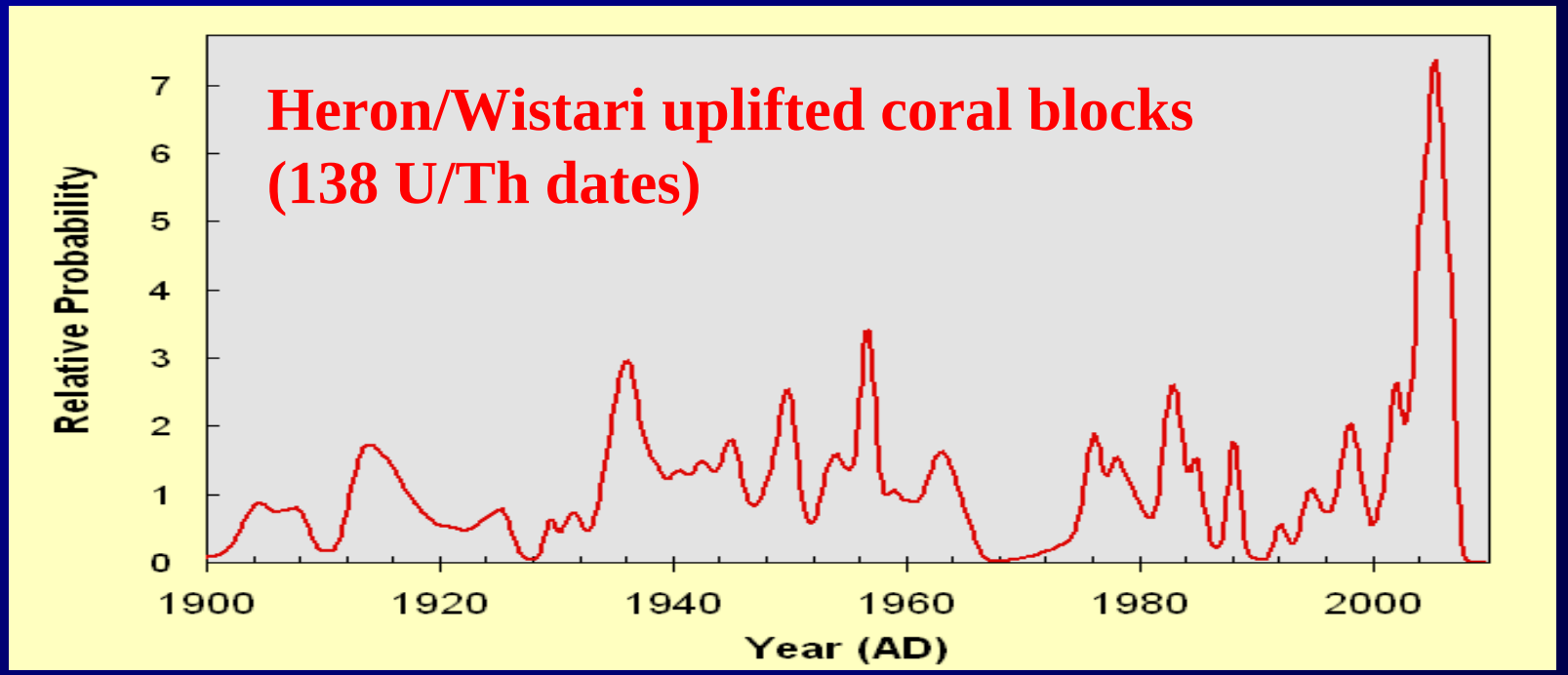
Mortality peaks match European settlement and PDO warm phases

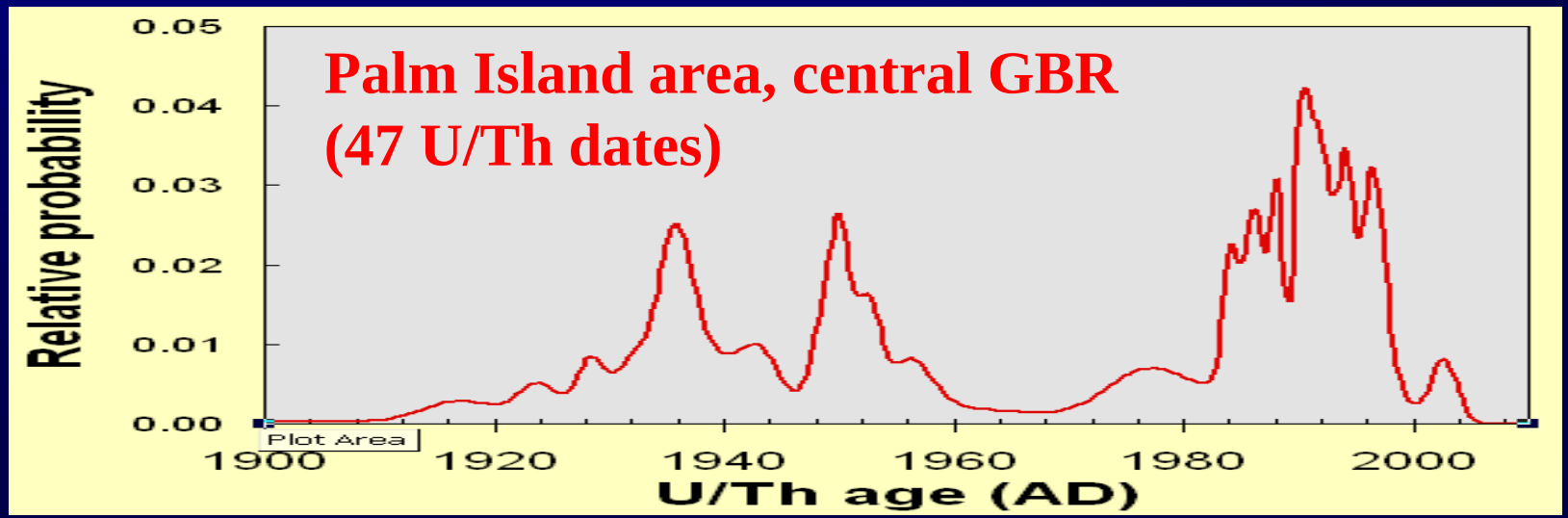
European Settlement





Highlight 6: Storm/cyclone records from Heron/Wistari Reefs





(Next talk by Kefu Yu)

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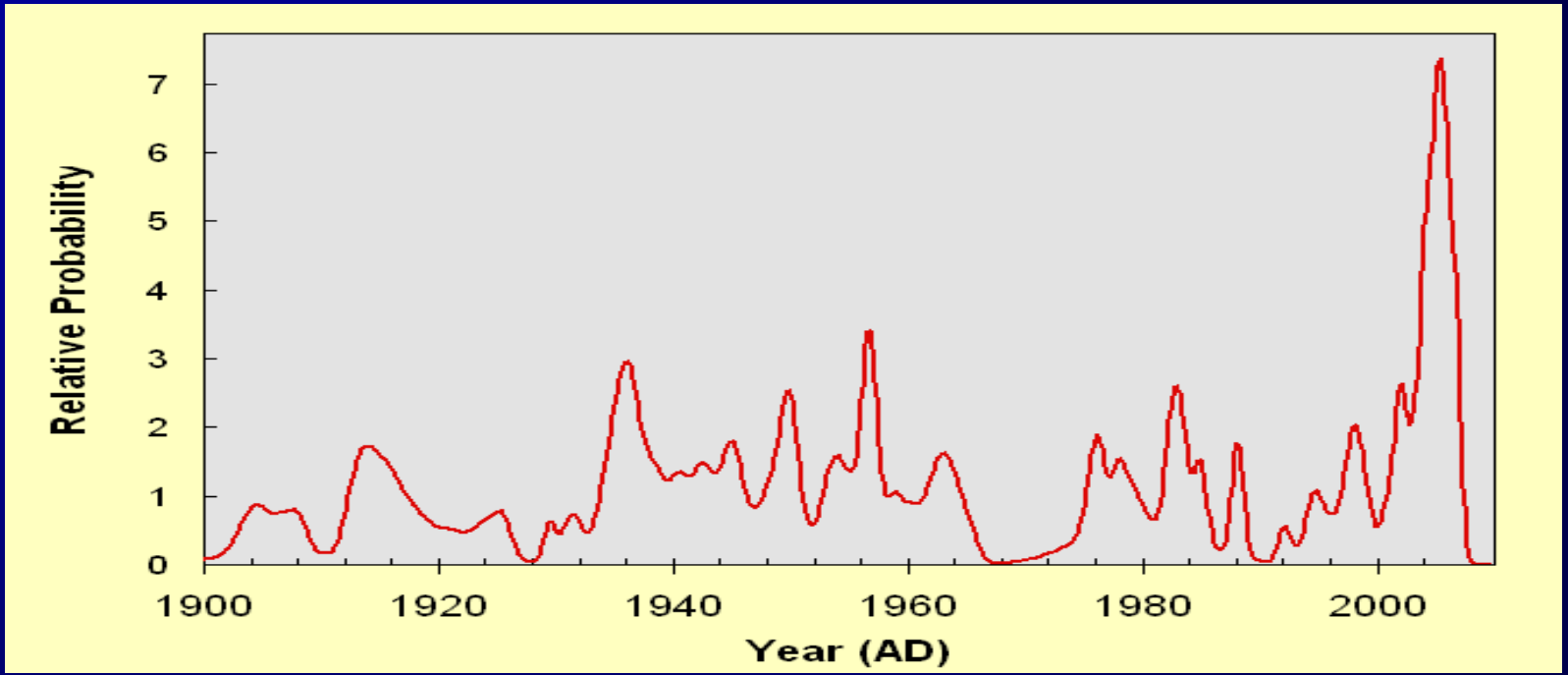

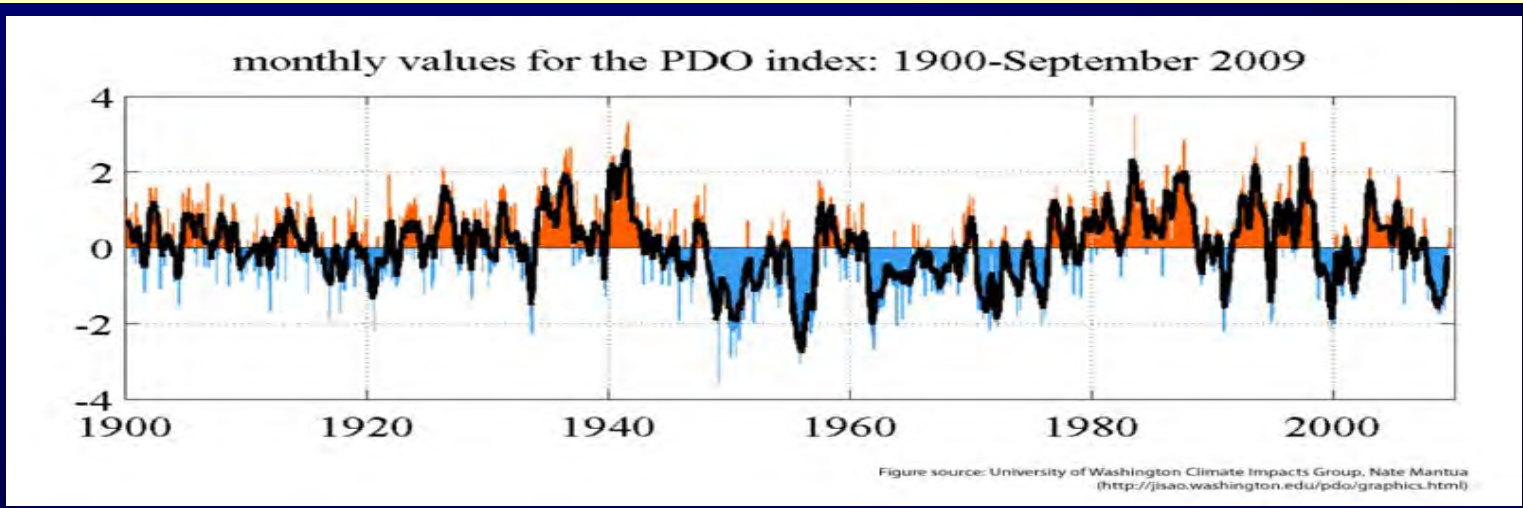

(Next talk by Kefu Yu)

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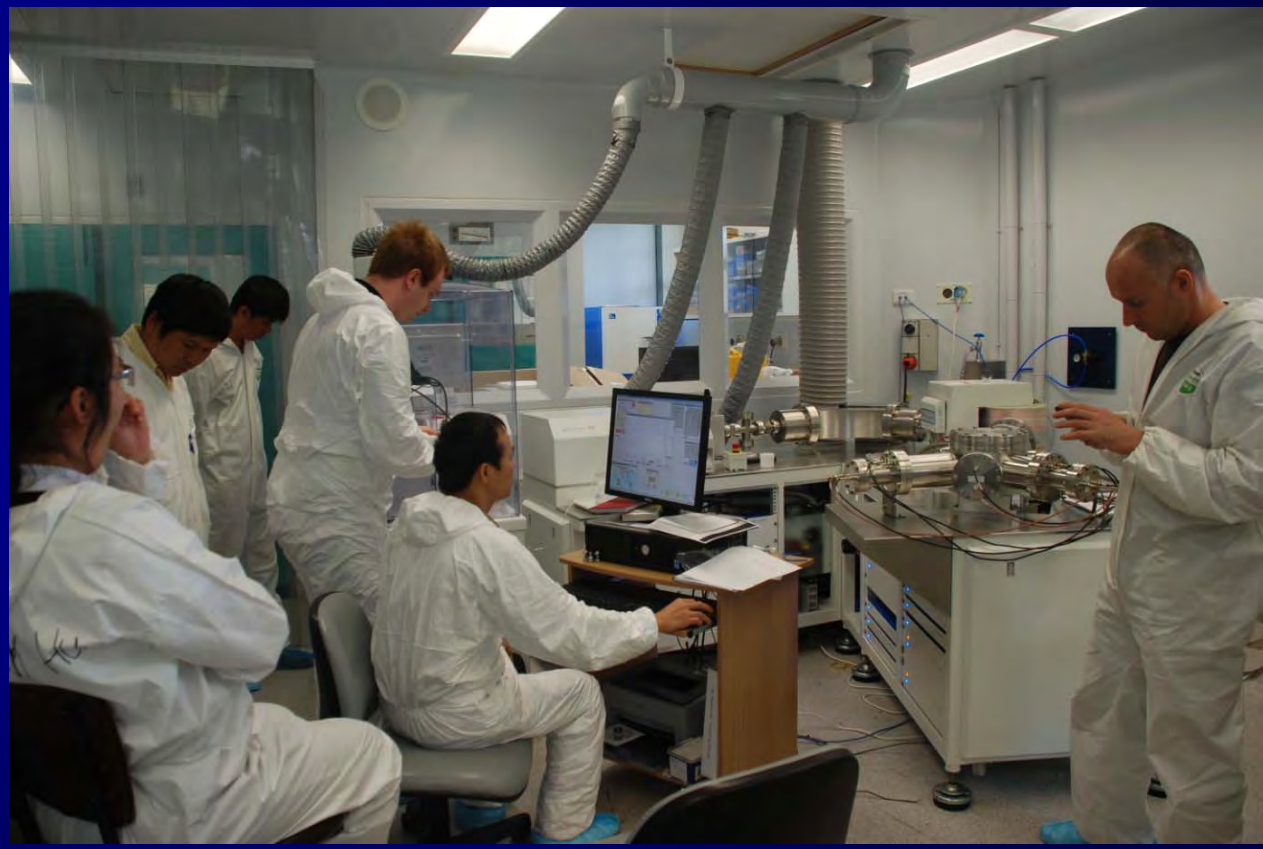
- Our work shows coral mortality events since European settlement can be dated with unprecedented resolution, enabling correlation with multiple cumulative stressors
- key challenges lie in (1) the analytical difficulty in dating extremely young corals and (2) bottleneck of our existing dating facility (the TIMS).



New ARC-LIEF-funded MC-ICP-MS installed in April 2010

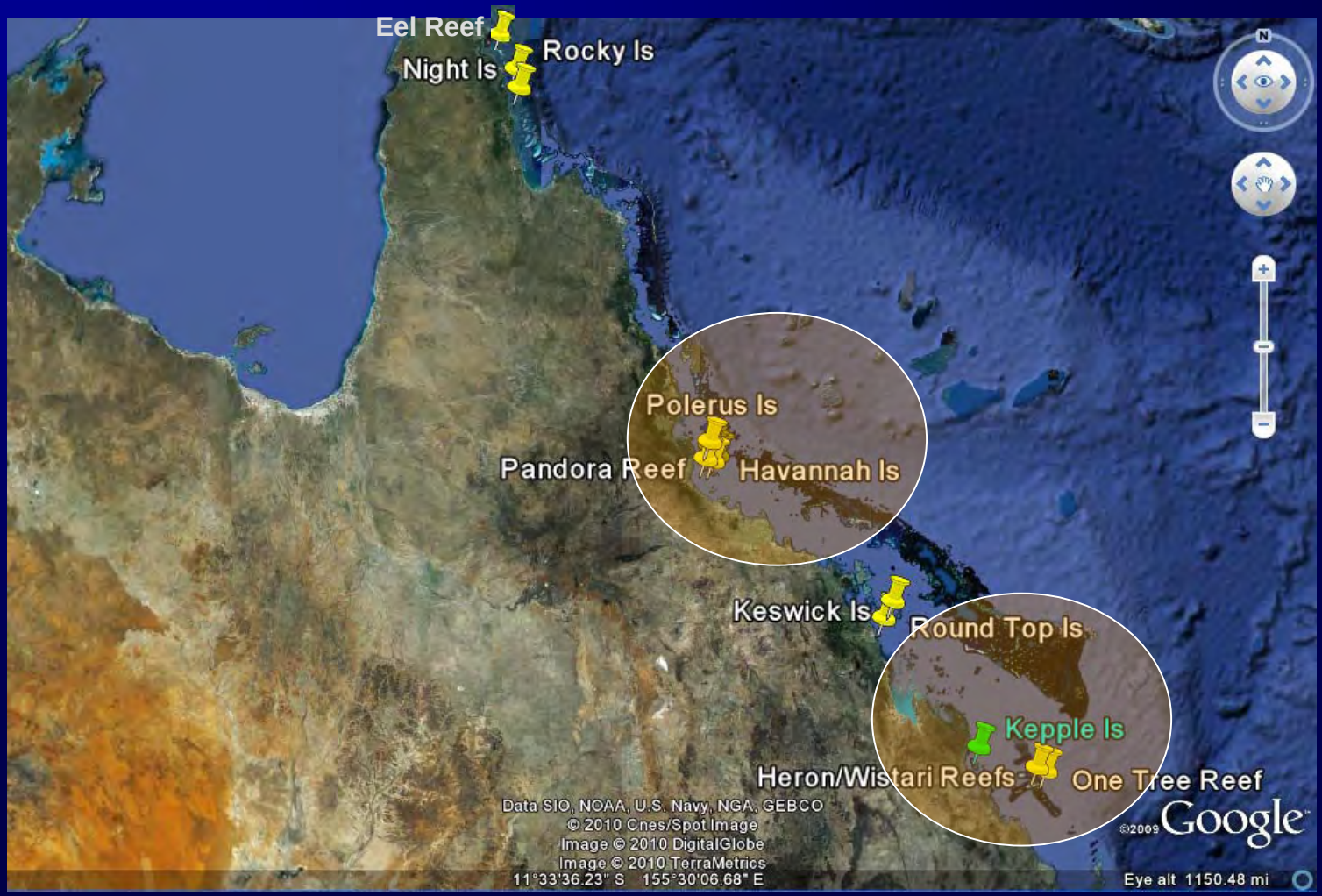
Now, both challenges have been resolved, and sample throughput for dating increased by 5-10 times with the new MC-ICP-MS

First set of U/Th dates from One Tree lagoon sediments determined on the new MC-ICP-MS

Sample Name	^{230}Th Age (yr)	±2σ
OT1-3-B2	3863	23
OT1-3-B5	3914	19
OT3A-B10	1445	8
OT3B-B47	1422	10
OT4-2-B1	2684	15
OT6-2-B16	2571	16
OT7-B38	693	6
OT7-B39	1714	12

- Determined in 4 hours on 13 May, vs. 2-3 days on TIMS
- Sample size significantly smaller than on TIMS

Future study will focus on fringing reefs severely influenced by Burdekin and Fitzroy River runoffs – sample across latitudinal/water quality gradients



Future study will focus on characterising the cumulative impacts of global, regional and local stressors on decadal, centennial and millennial scales to identify the effects of European settlement on GBR coral reef communities

- Characterize reef ecological changes over the past millennium to understand causes of reef degradation since European settlement
- Determine the timing, rates and patterns of coral mortality and recovery over the past millennium to identify trends since European settlement
- Determine inshore reef calcification/accretion rates over the past millennium
- Quantify decadal sea-level, sea-surface temperature, salinity and ENSO variability over the past millennium
- Characterize GBR seawater acidity change over the past millennium to identify trends since Industrial Revolution and European settlement
- Characterize pre- vs. post- European settlement GBR seawater trace metal and turbidity change through geochemical analysis of coral cores
- Reconstruct cyclone frequency and trend over the past millennium


Thank you!