Late Quaternary Shelf Edge and Upper Slope Deposition in Low Latitude Mixed Siliciclastic/Carbonate Systems: Lessons from the Gulf of Papua, and the Western Texas Shelf*

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Abstract

Although siliciclastic/carbonate mixed systems are common in the geological record and interesting because siliciclastic and carbonate components can interact over space and time, modern examples of mixed continental margins remain poorly studied. We present a review dedicated to late Quaternary shelf edge and slope deposition in mixed systems, by integrating recent observations from the Gulf of Papua, the Western Texas Shelf, and the Belize Margin. These regions are characterized by large volume of siliciclastic sand and mud juxtaposed to areas of major neritic carbonate production. These modern analogues are used to develop a quantitative understanding of shelf edge barrier reef edification and sediment transport and accumulation across and along adjacent slopes at different segments of relatively well established sea level cycle. Sharp siliciclastic-to-carbonate switch on the shelf edge and carbonate-to-siliciclastic switch on the upper slopes, correspond to times of initial sea level rise following the Last Glacial Maximum (MIS-2) and the initial onset of sea level fall at the end of last interglacial (MIS-5e), respectively.

Onset of rapid sea level rise during the early deglaciation, when siliciclastics are deposited along newly formed coasts on up dip positions, became opportune time windows for coralgal communities to establish themselves on top of maximum lowstand (MIS-2) coastal siliciclastic deposits, such as beach ridges and lowstand shelf edge deltas. Coralgal communities built 30 to 50 m-high edifices during the first part of last deglaciation in 5 to 6 ky, and then drowned, when sea level rose again after the Younger Dryas, a 1 ky-long cooler interval when sea level remain stable.

On the upper slope, almost pure carbonates, a mixture of mostly bank-derived fine aragonite and magnesian calcite and some pelagic calcite, accumulated during maximum sea level highstand (MIS-5e) when the neritic carbonate production was at its maximum. This carbonate unit is overlain by an almost pure siliciclastic mud unit thinning down the slope. During the late interglacial interval (MIS-5d to 5a) following the maximum highstand (MIS-5e), a rapid ~ 50 m sea fall destabilized thick unlithified siliciclastic muds, stored as today on inner/mid shelf clinothems during the penultimate highstand, through exposure, reworking, transport as suspended material across the narrowed continental shelf, to be ultimately delivered along the shelf margin to the upper slope.

References

Chappell, J., 2002, Sea level changes forced ice breakouts in the last glacial cycle; new results from coral terraces, *in* M. Sarnthein, and J.P. Kennett, (eds.), Decadal-to-millennial-scale climate variability: Quaternary Science Reviews, v. 21/10, p. 1229-1240.

Harris, P.T., E.K. Baker, A.R. Cole, and S.A. Short, 1993, A preliminary study of sedimentation in the tidally dominated Fly River Delta, Gulf of Papua: Continental Shelf Research, v. 13, p. 441-472.

Milliman, J.D., 1995, Sediment discharge to the ocean from small mountainous rivers; the New Guinea example, in C.A. Nittrouer, (ed.), Tropical coastal sedimentary environments: GeoMarine Letters, v. 15/3-4, p. 127-133.

Tcherepanov, E., A.W. Droxler, P. Lappointe, G.R. Dickens, S.J. Bentley, L. Beaufort, L.C. Peterson, J.J. Daniell, and B. Opdyke, 2008, Neogene evolution of the mixed carbonate-siliciclastic system in the Gulf of Papua, Papua New Guinea: Journal Geophysical Research, v. 113, p. F01S21.

Weight, R.W.R., J.B. Anderson, and R.A. Fernandez, 2011, Rapid mud accumulation on the central Texas shelf linked to climate change and sea-level rise: JSR, v. 81/10, p. 743-761.

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Long Beach, April 24, 2012

Shelf Edge and Upper Slope Carbonate to Siliciclastic Switch(es)

André Droxler,

Stephan J. Jorry, Jason Francis,
Brooke Carson, Gianni Mallarino,
Andrei Belopolsky, Elmer Ferro

Palma, April 10, 2012

Last 150 kyr, well established Sea Level curve

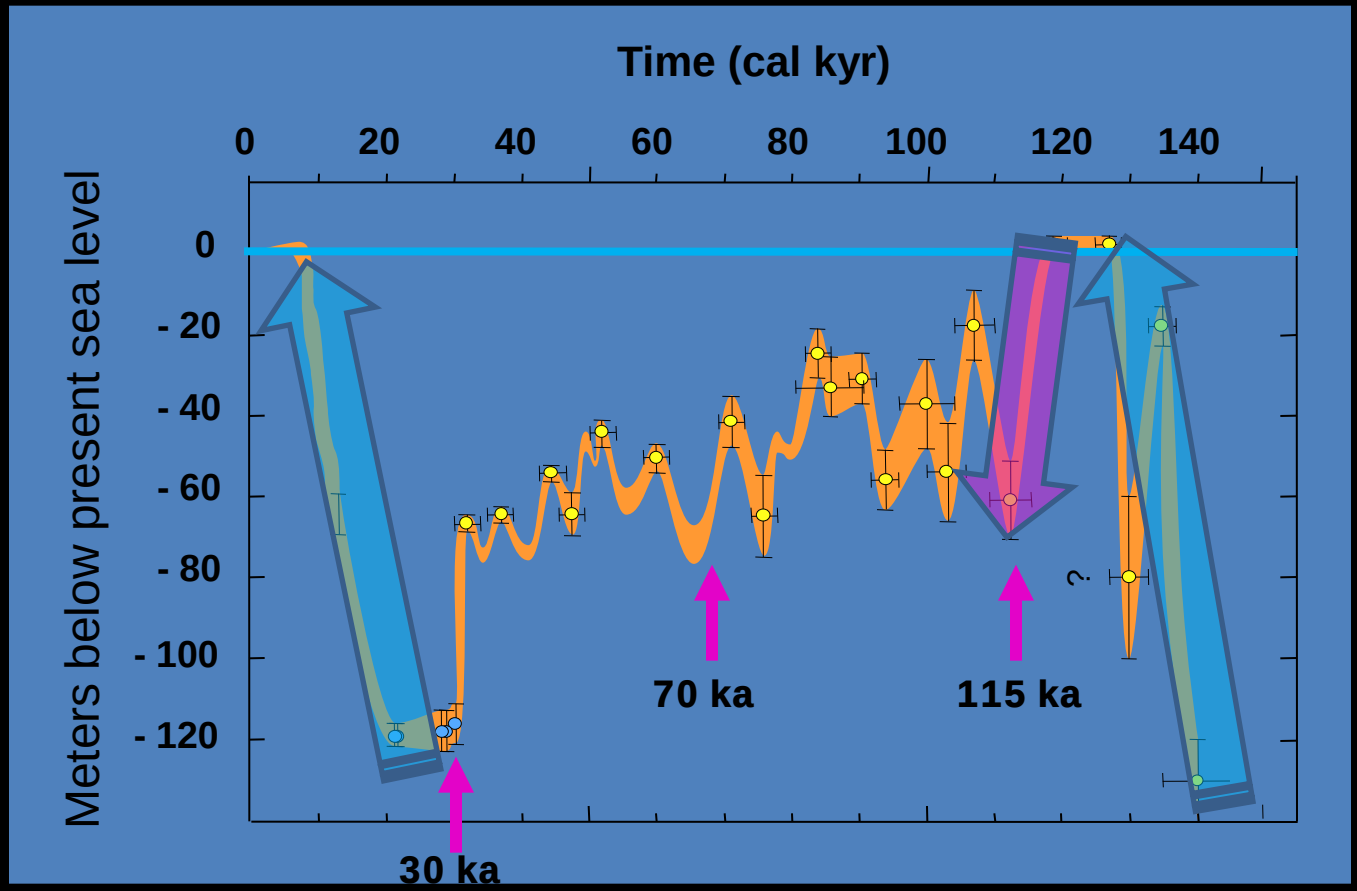
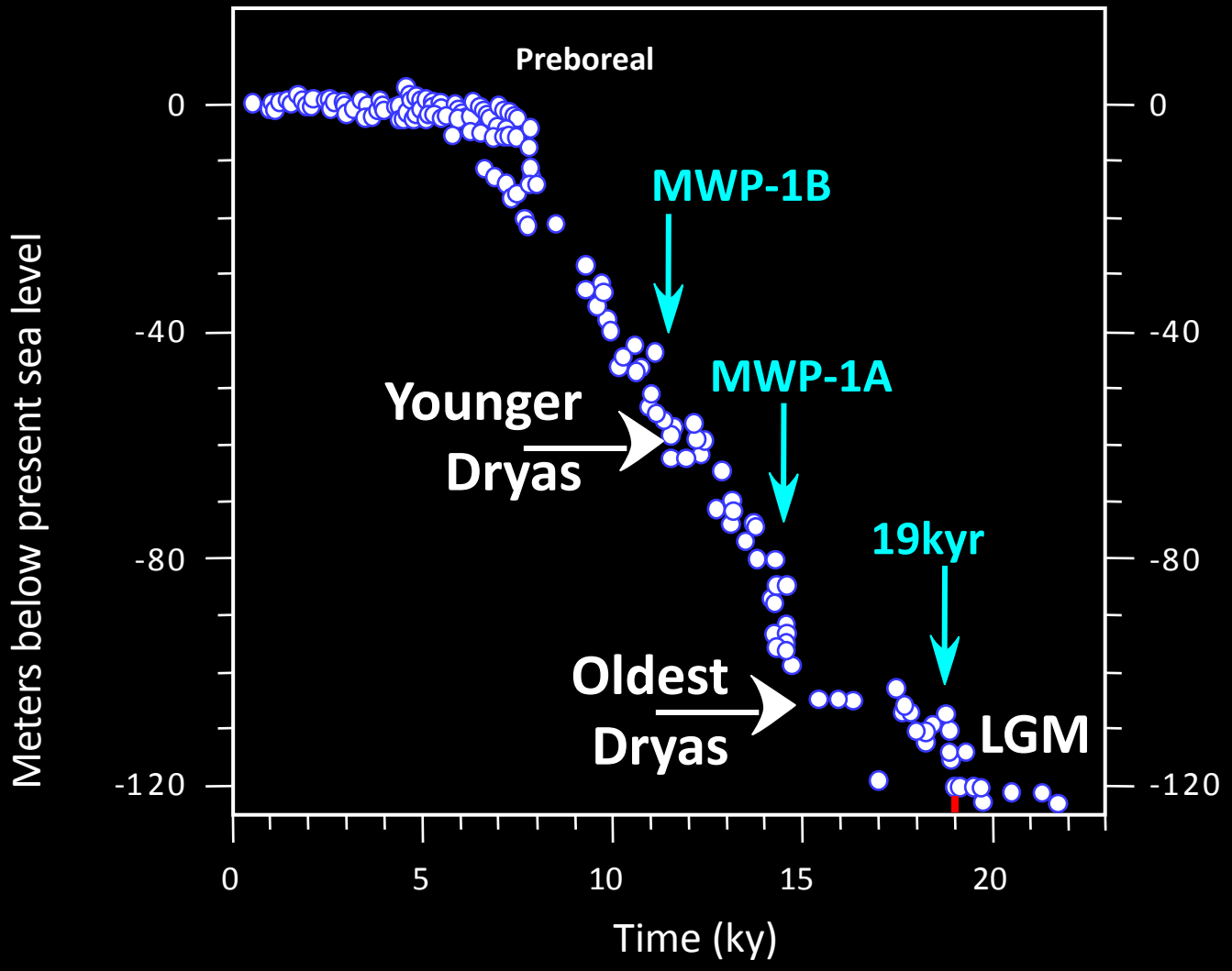
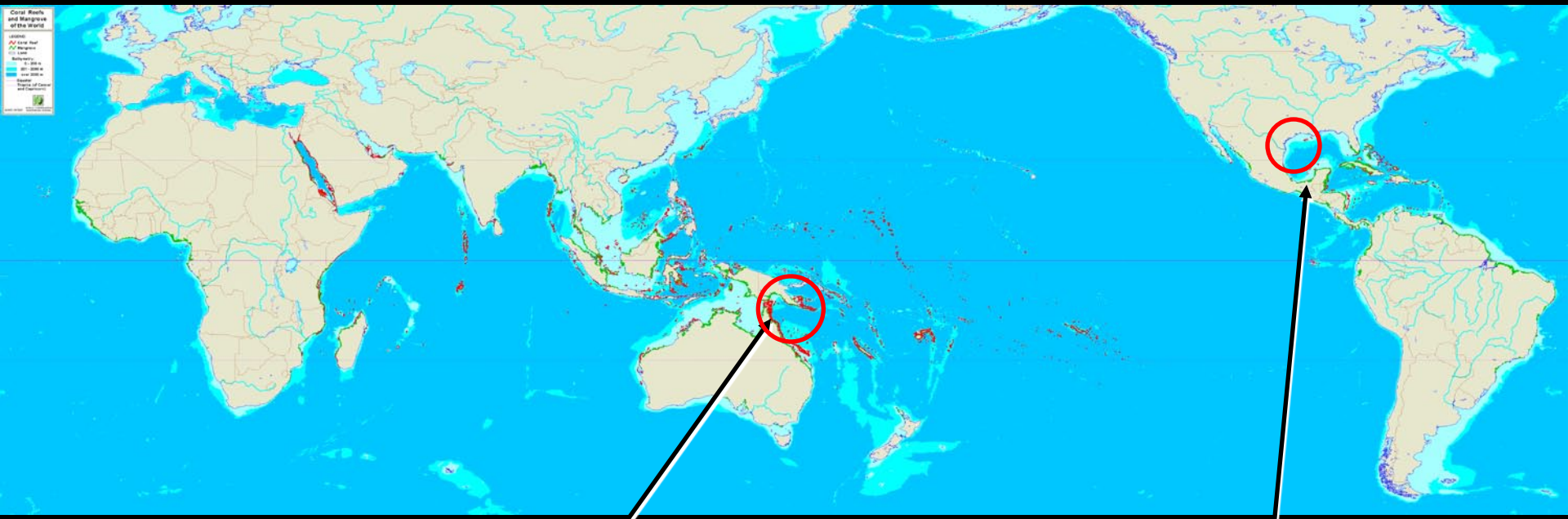


Figure from Chappell, 2002

Sea Level Variations since Last Glacial Maximum



Mixed Cabonate Siliciclastic Sedimentary Systems in Low Latitudes

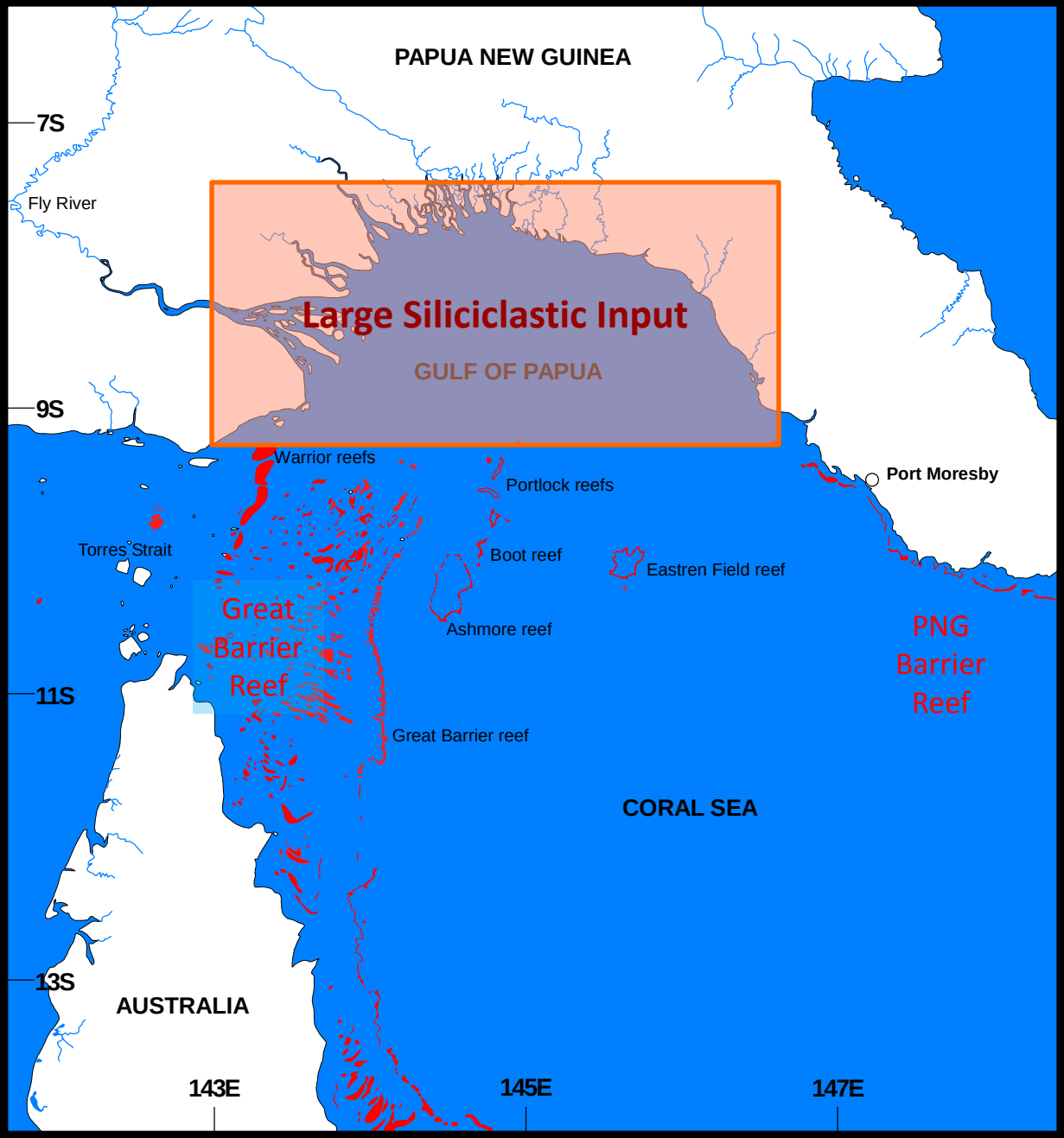


Gulf of Papua

Western Texas Shelf

Source of global reef map: http://www.wcmc.org.uk/marine/data/coral_mangrove/marine.maps.main.html

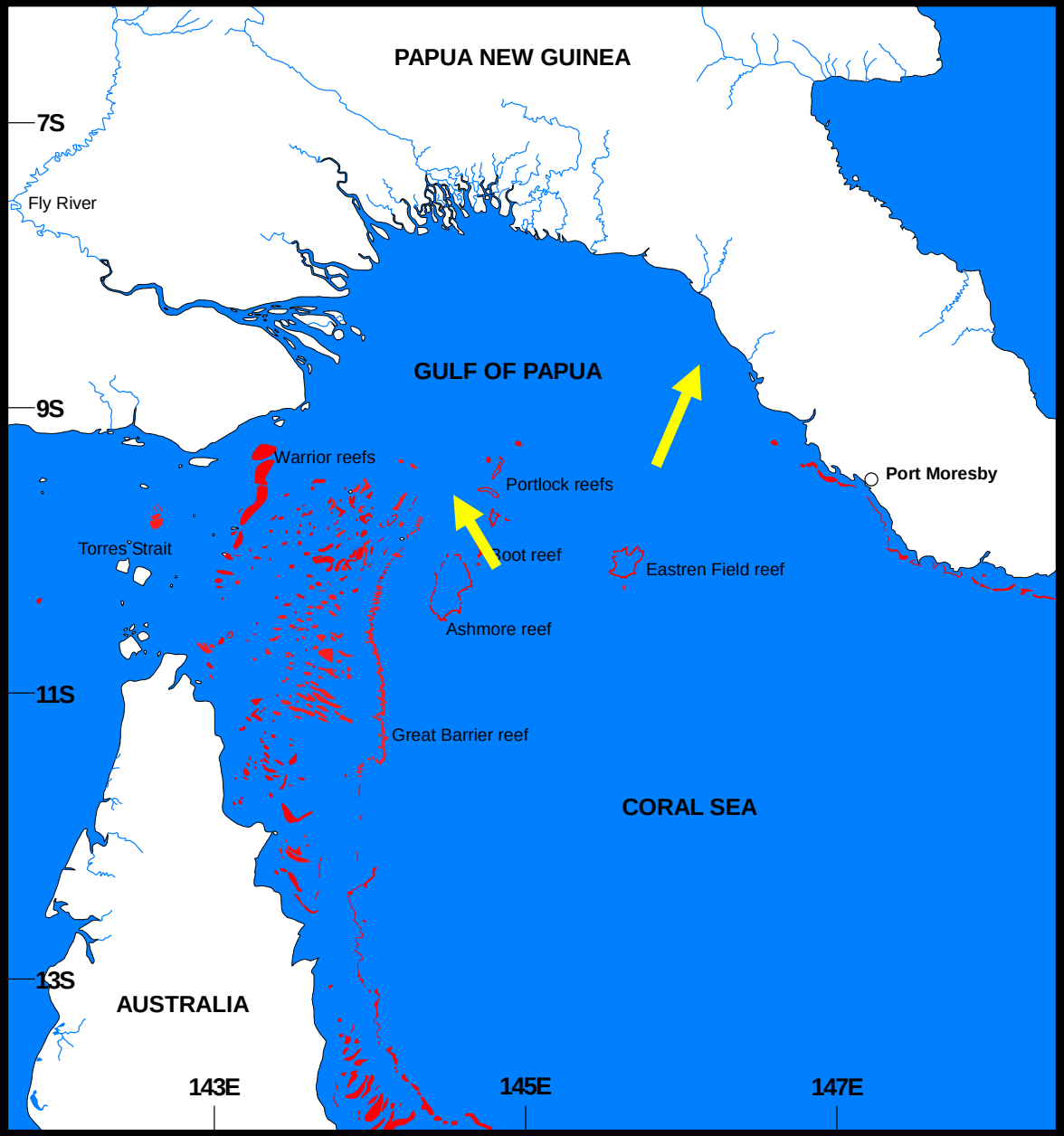
The Gulf of Papua



Sediments from the rivers =

200-300 Mt/y

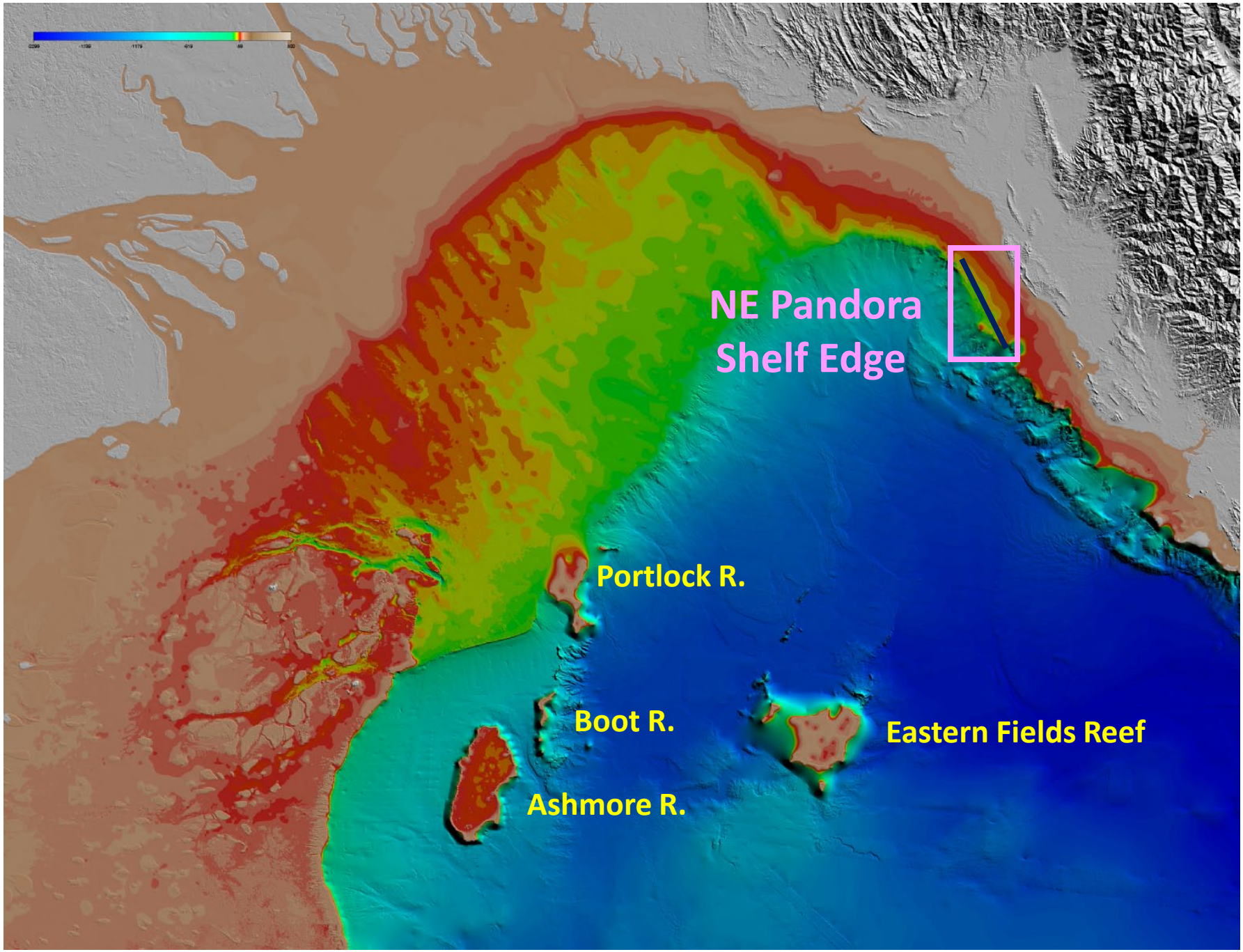
(*Harris et al.*, 1993; *Milliman*, 1995)

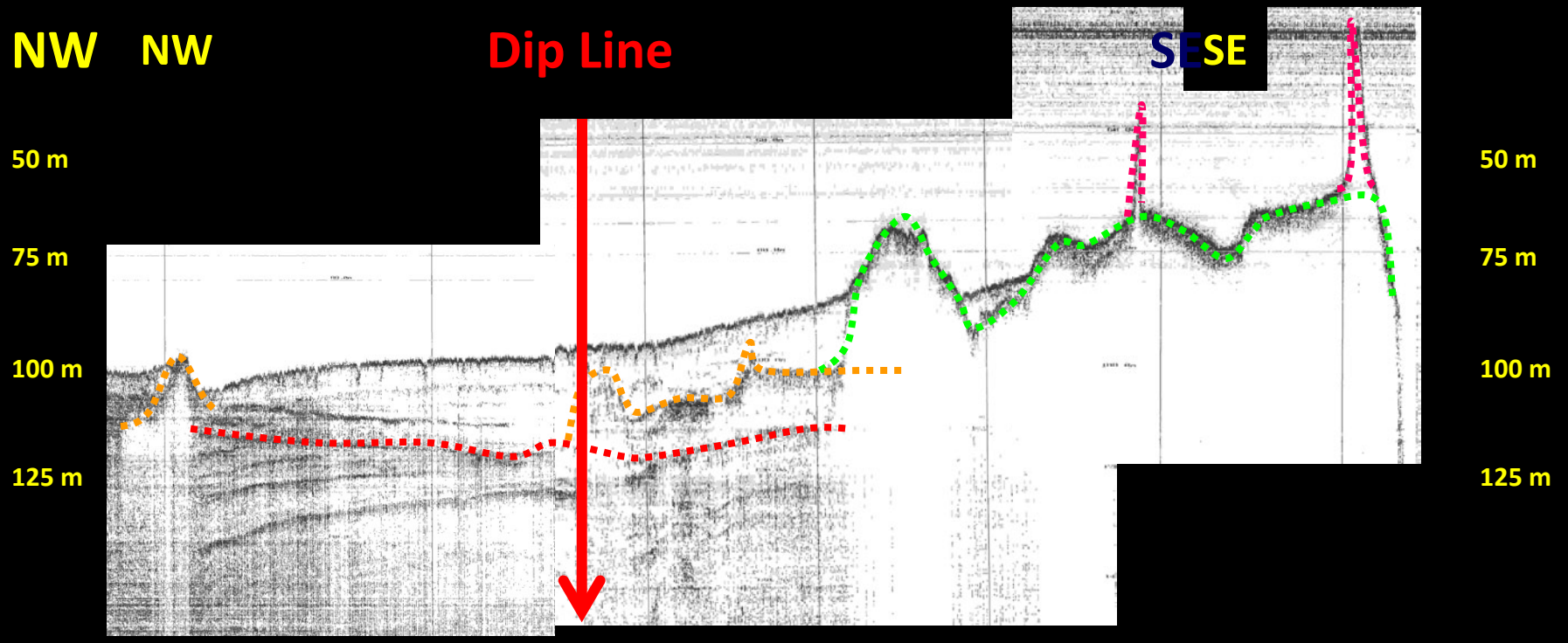


The Gulf of Papua

PNG BR & Geat BR

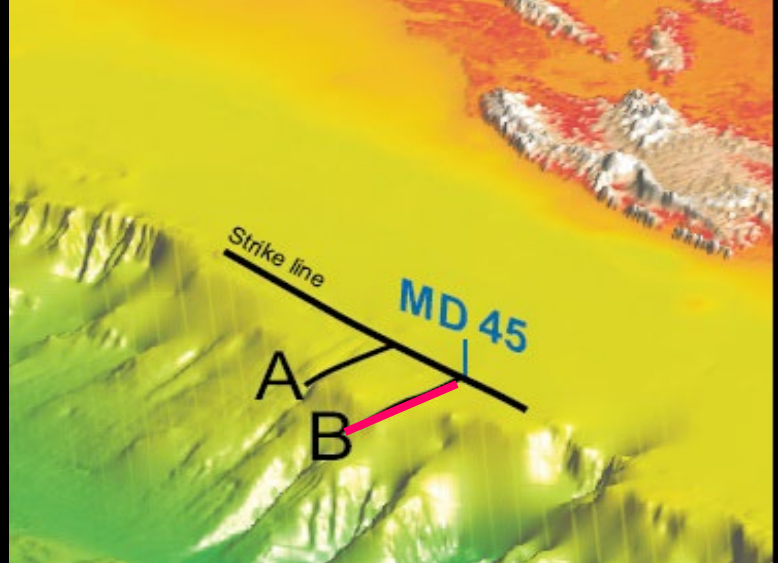
Short lived Drowned Barriers on their northern extremities

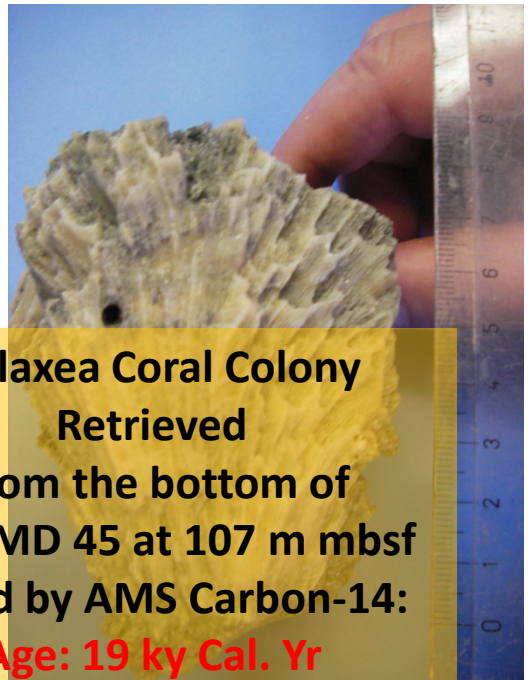

NE Pandora
Shelf Edge
Portlock R.
Boot R.
Eastern Fields Reef
Ashmore R.



R/V Melville 2004 PANASH Strike line

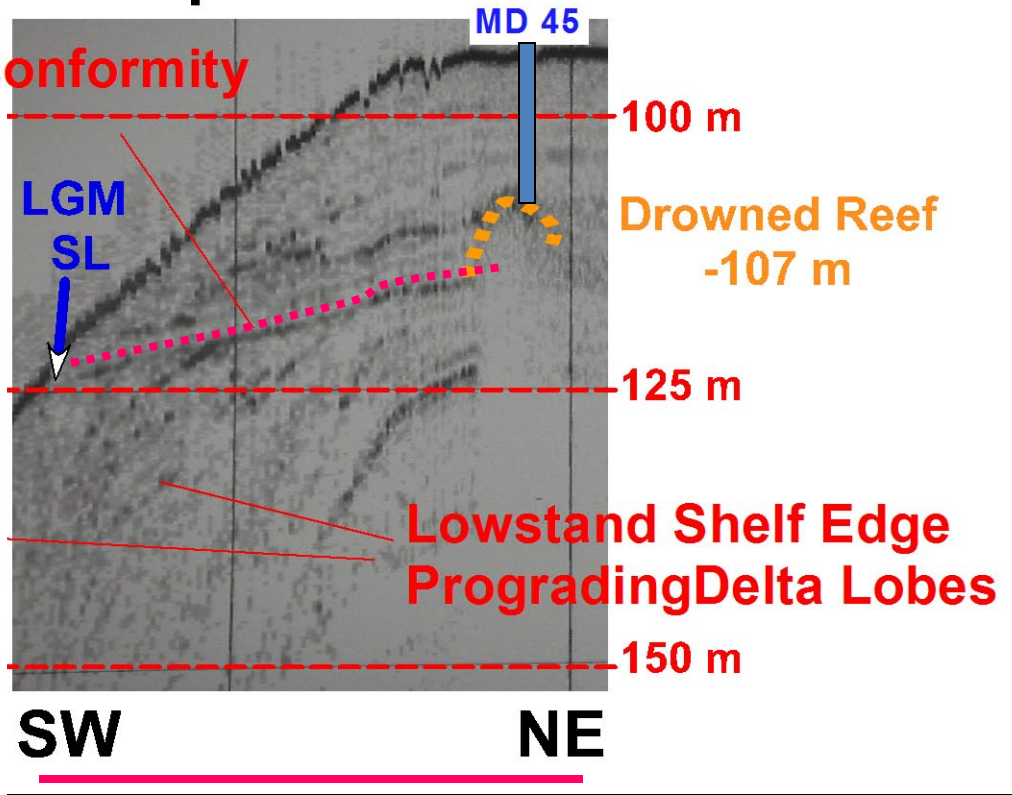
R/V Marion Dufresne
2005 PECTEN

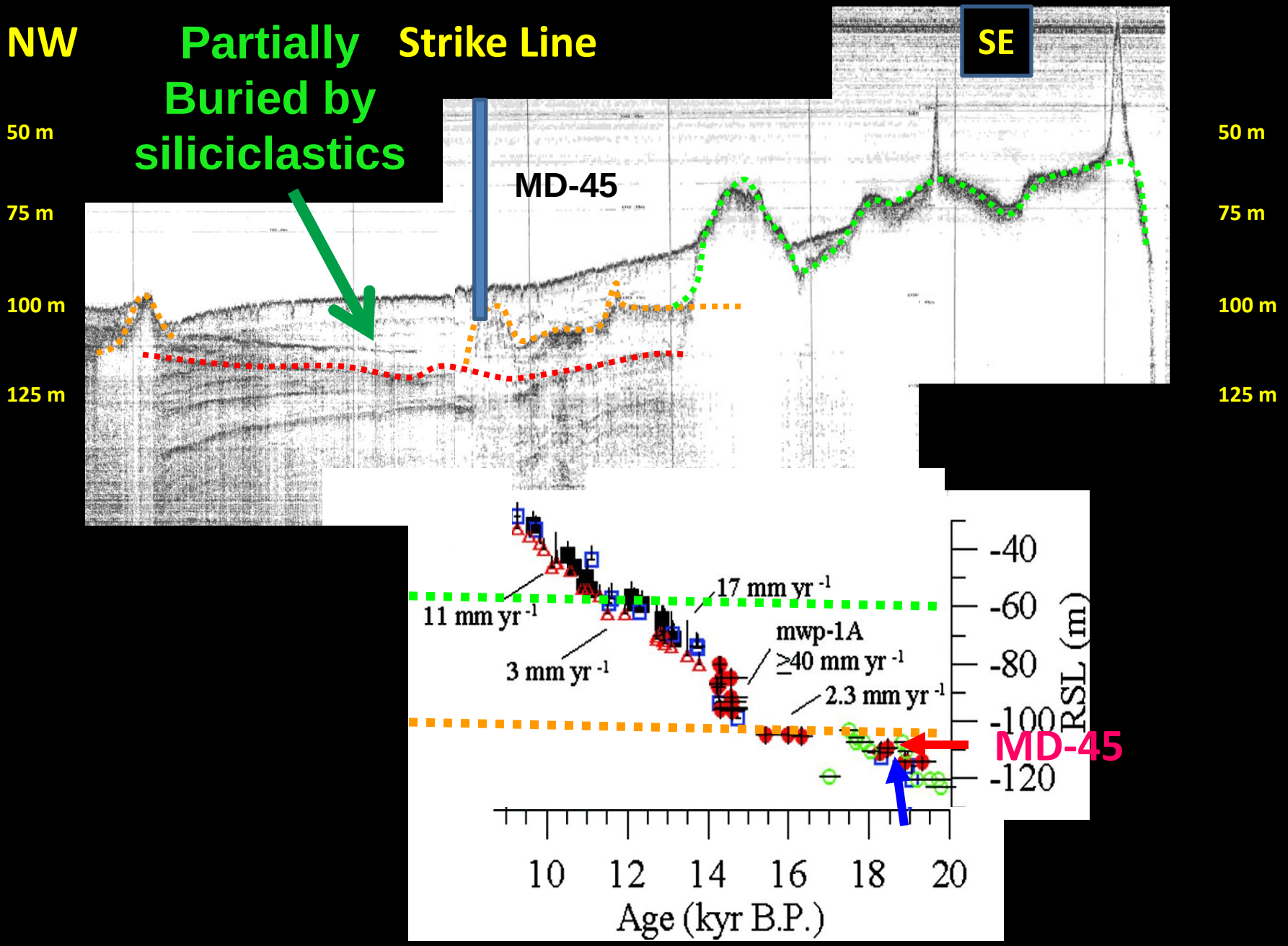


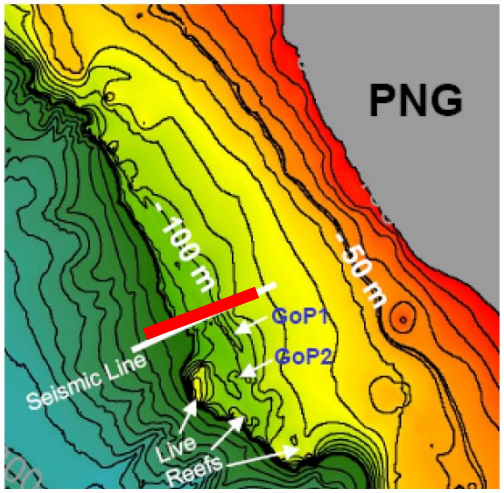


Galaxea Coral Colony
Retrieved
from the bottom of
Core MD 45 at 107 m mbsf
Dated by AMS Carbon-14:
Age: 19 ky Cal. Yr

Dip Line B




NW
Partially Buried by siliciclastics
Strike Line
SE
MD-45
50 m
75 m
100 m
125 m
50 m
75 m
100 m
125 m
11 mm yr -1
17 mm yr -1
3 mm yr -1
mwp-1A
≥40 mm yr -1
2.3 mm yr -1
MD-45
-40
-60
-80
-100
-120
RSL (m)
10
12
14
16
18
20
Age (kyr B.P.)



NW Fugro Multi Client Services, Inc. seismic line **SE**

0.0

0.3

0.6

TWT in sec.

Lowstand unconformity

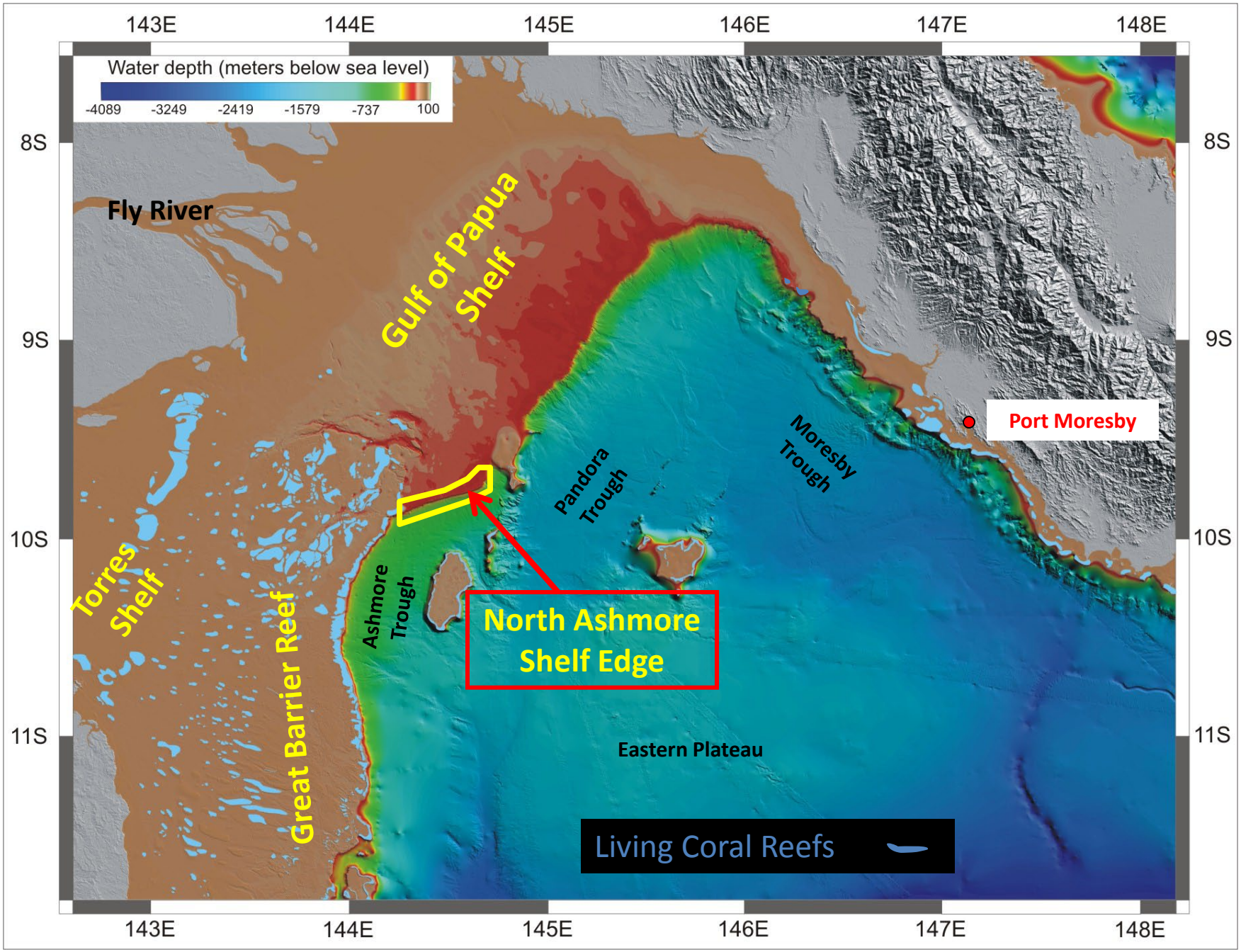
Drowned Transgressive Reefs

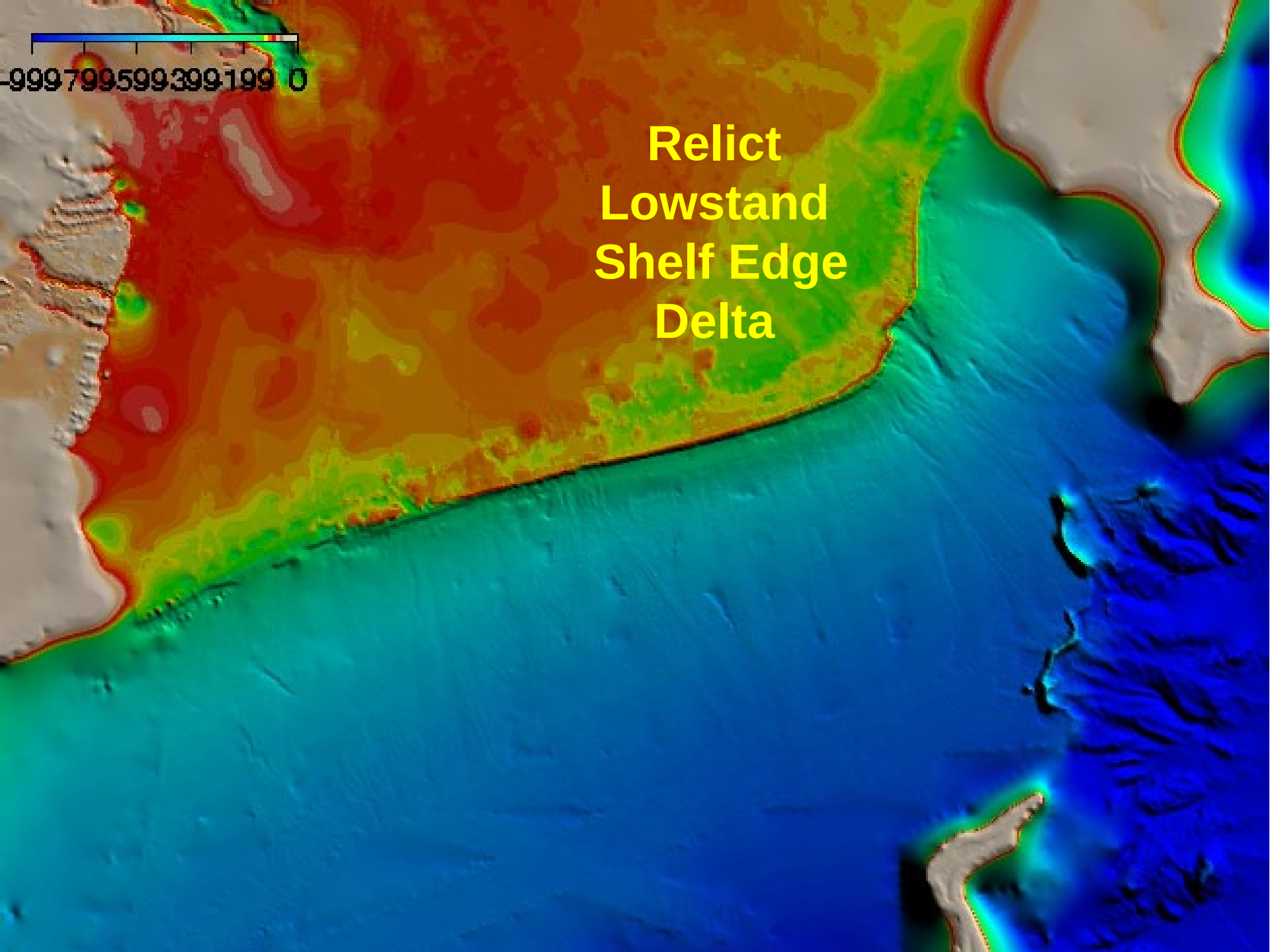
Prograding regressive shelf edge delta lobes

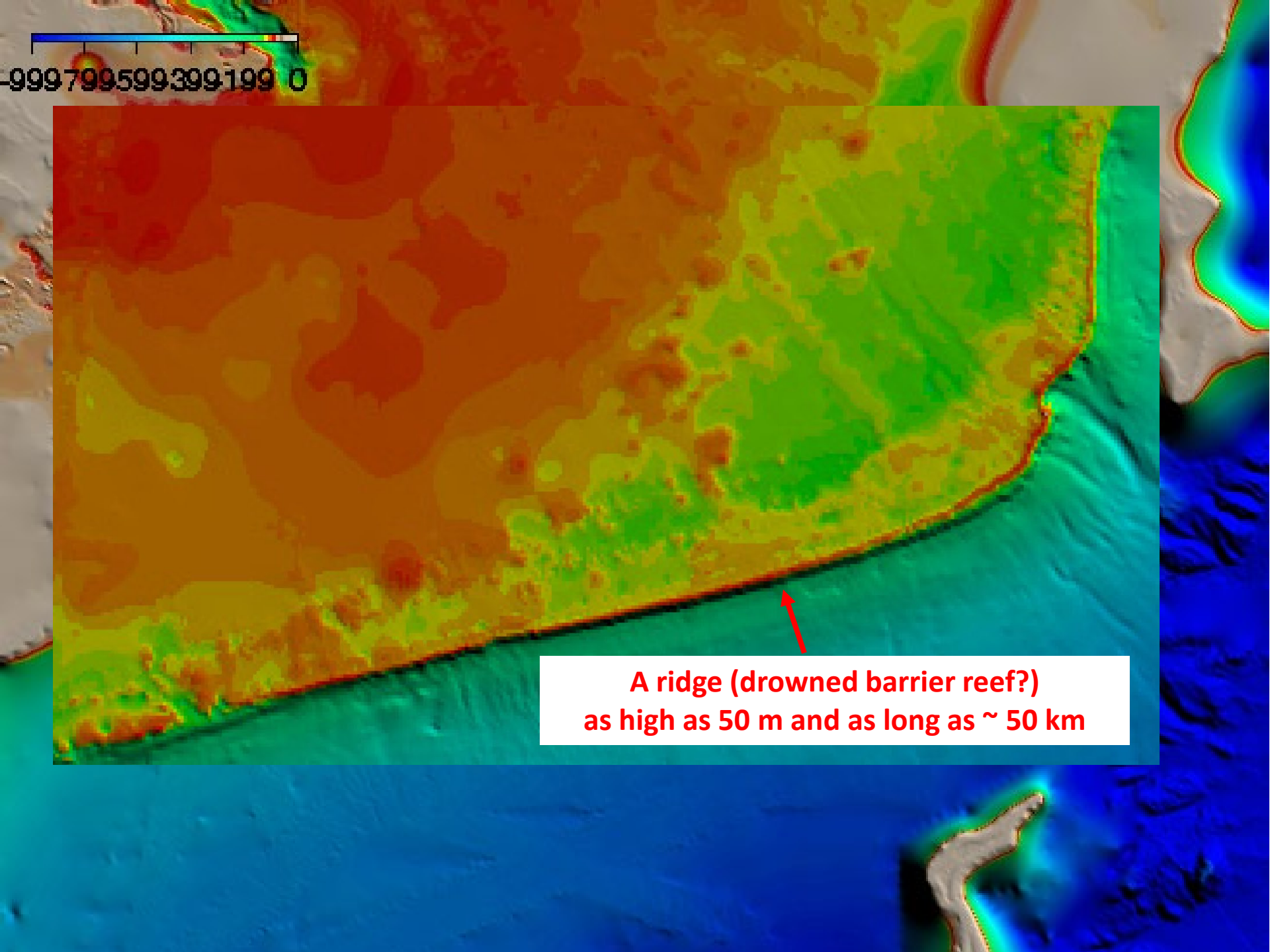
Previous Shelf Edge Reefs?

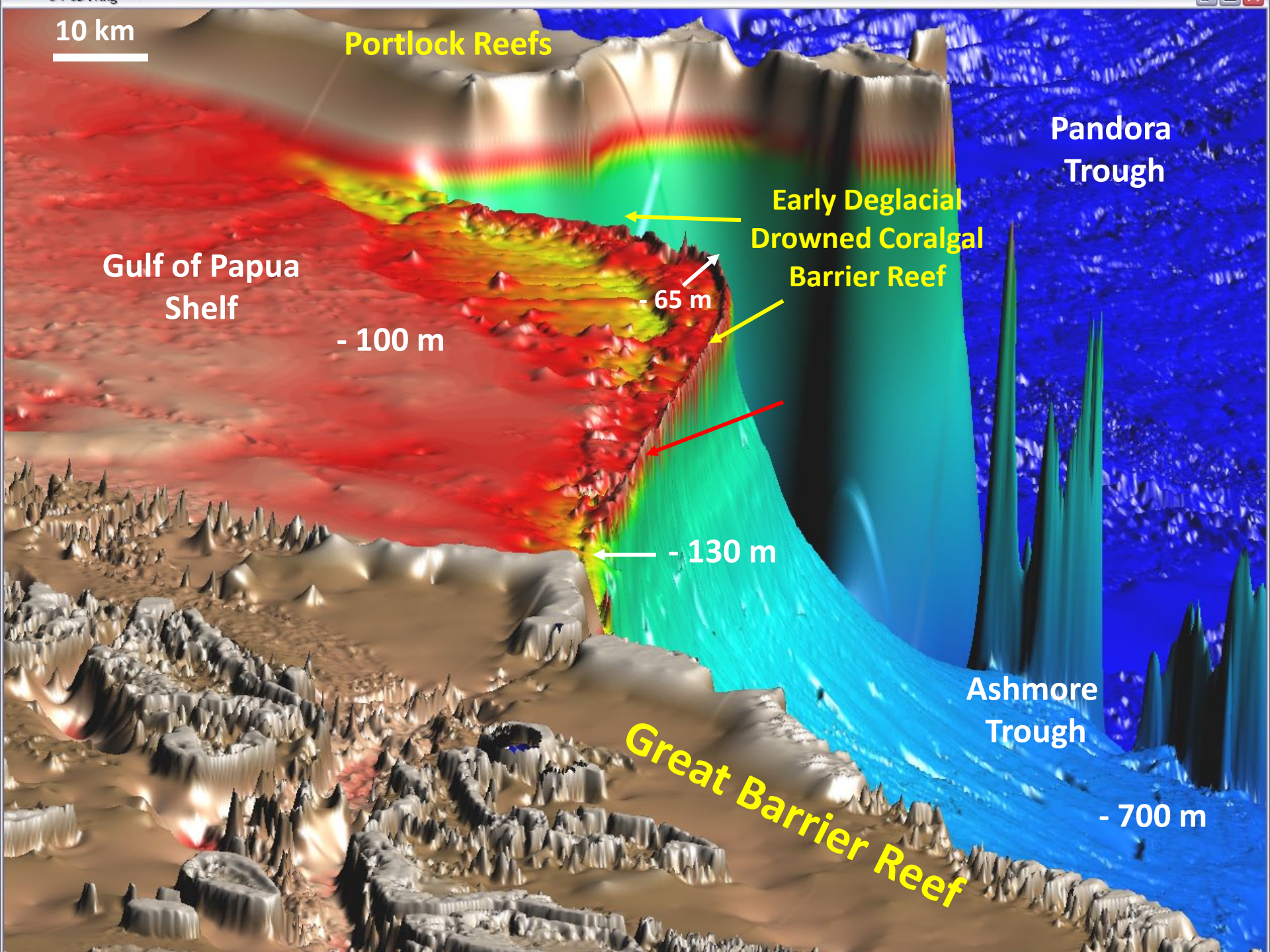
Line 81-518

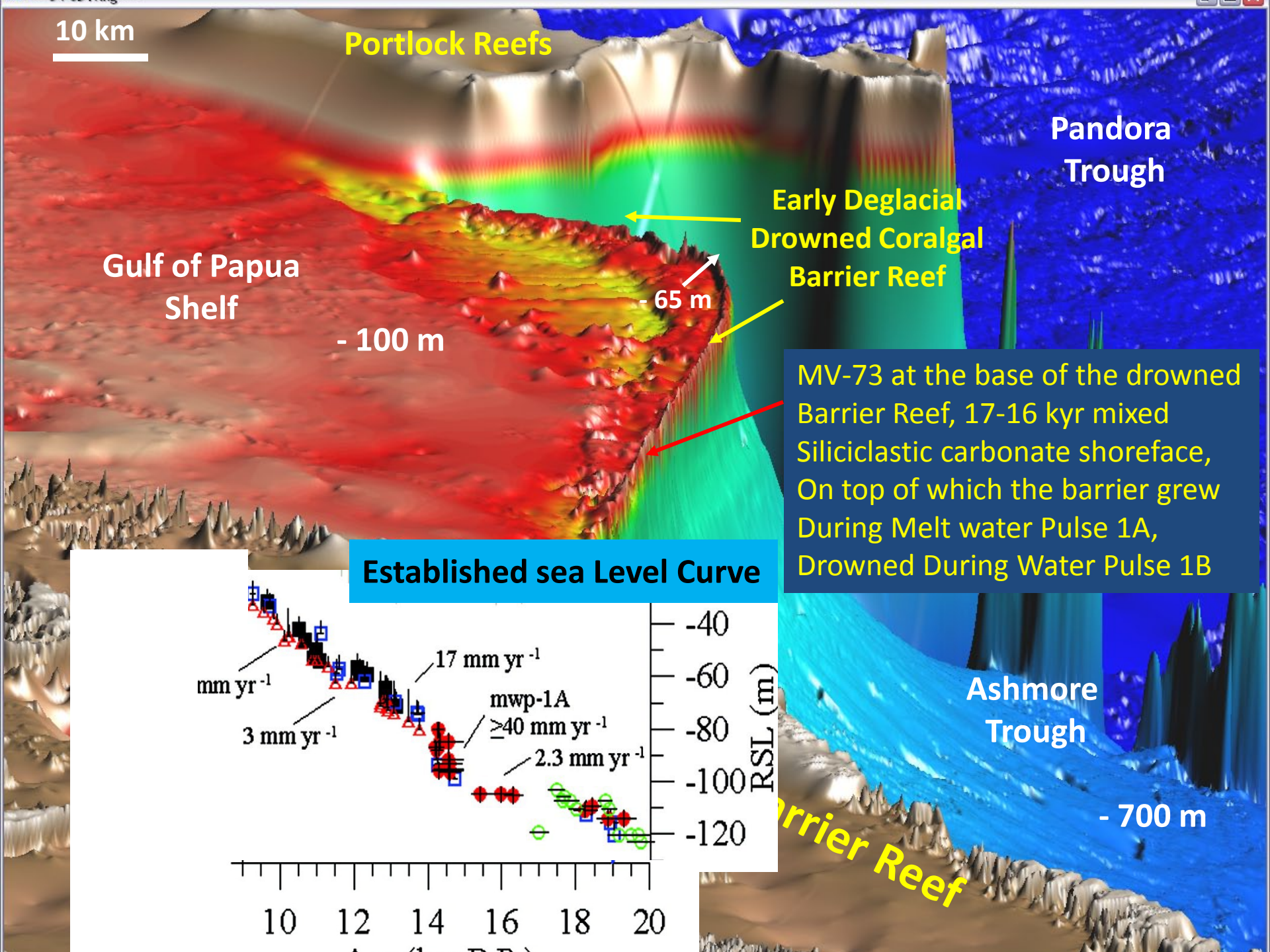
2 km

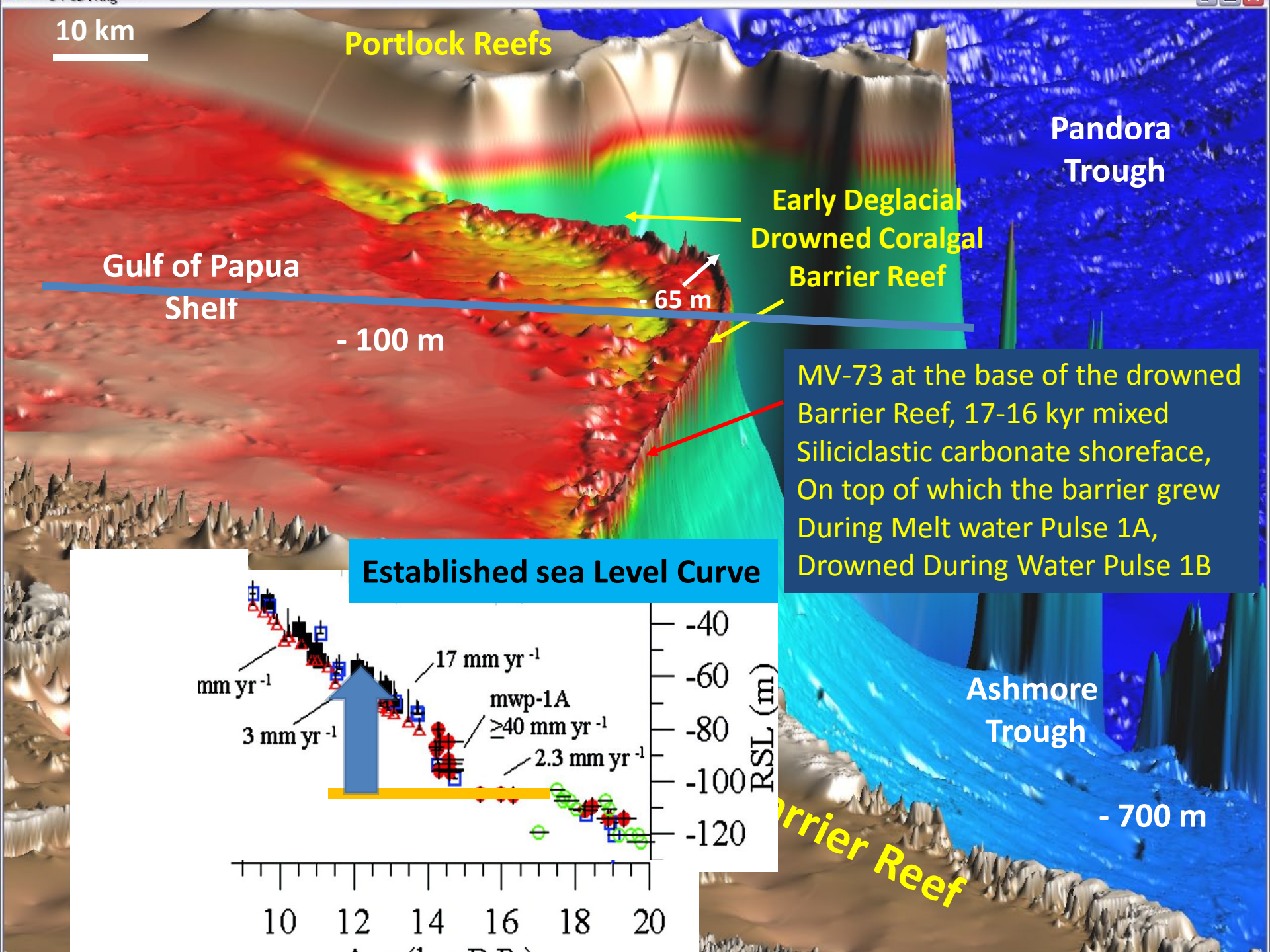

143E
144E
145E
146E
147E
148E
8S
9S
10S
11S
Water depth (meters below sea level)
-4089
-3249
-2419
-1579
-737
100
Fly River
Gulf of Papua Shelf
Port Moresby
Moresby Trough
Pandora Trough
Torres Shelf
Ashmore Trough
Great Barrier Reef
North Ashmore Shelf Edge
Eastern Plateau
Living Coral Reefs


-9997995993991990
Relict
Lowstand
Shelf Edge
Delta


-9997995993991990
A ridge (drowned barrier reef?)
as high as 50 m and as long as ~ 50 km


10 km
Portlock Reefs
Pandora Trough
Early Deglacial Drowned Coralgal Barrier Reef
Gulf of Papua Shelf
- 65 m
- 100 m
- 130 m
Ashmore Trough
Great Barrier Reef
- 700 m


10 km
Portlock Reefs
Pandora Trough
Early Deglacial Drowned Coralgal Barrier Reef
Gulf of Papua Shelf
- 65 m
- 100 m
MV-73 at the base of the drowned Barrier Reef, 17-16 kyr mixed Siliciclastic carbonate shoreface, On top of which the barrier grew During Melt water Pulse 1A, Drowned During Water Pulse 1B
Established sea Level Curve
mm yr -1
3 mm yr -1
17 mm yr -1
mwp-1A
≥40 mm yr -1
2.3 mm yr -1
-40
-60
-80
-100
-120
RSL (m)
10
12
14
16
18
20
Ashmore Trough
- 700 m
rrier Reef


10 km
Portlock Reefs
Pandora Trough
Early Deglacial Drowned Coralgal Barrier Reef
Gulf of Papua Shelf
- 65 m
- 100 m
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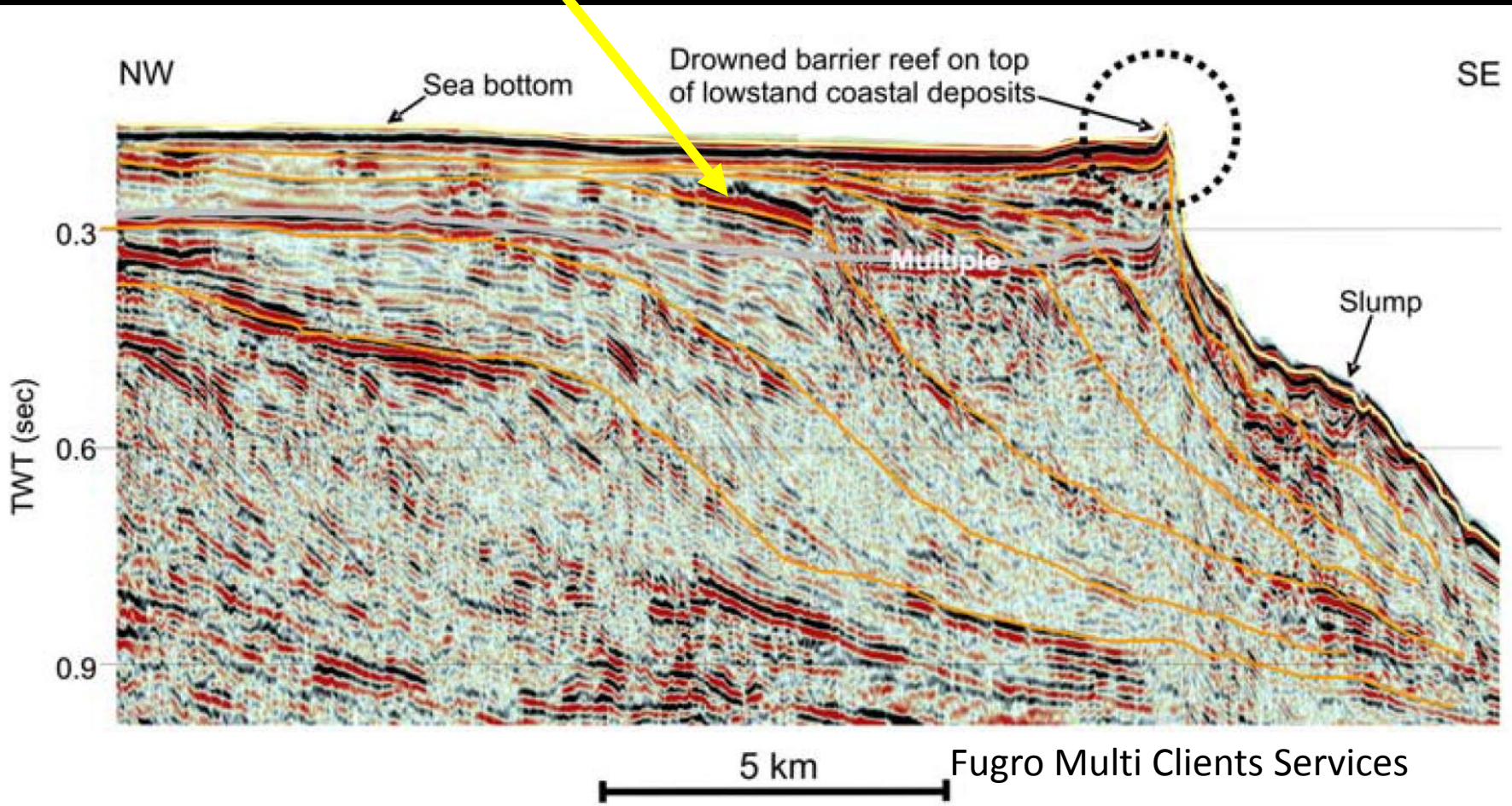
-40
-60
-80
-100
-120
RSL (m)
10
12
14
16
18
20
Ashmore Trough
- 700 m
rrier Reef

Buried Earlier Transgressive Barrier Reefs



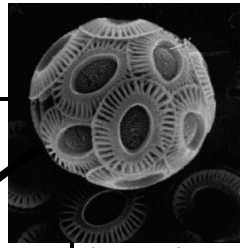
Fugro Multi Clients Services

Slope Periplatform Carbonates
In mixed systems

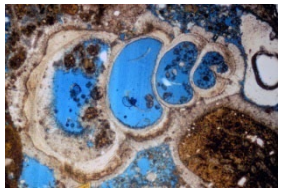
Neritic Sources
Green algae (e.g., *Halimeda*)
Corals (aragonite)
Mollusks (aragonite)
Benthic Foraminifers (HMC)
Echinoderms (HMC), etc.

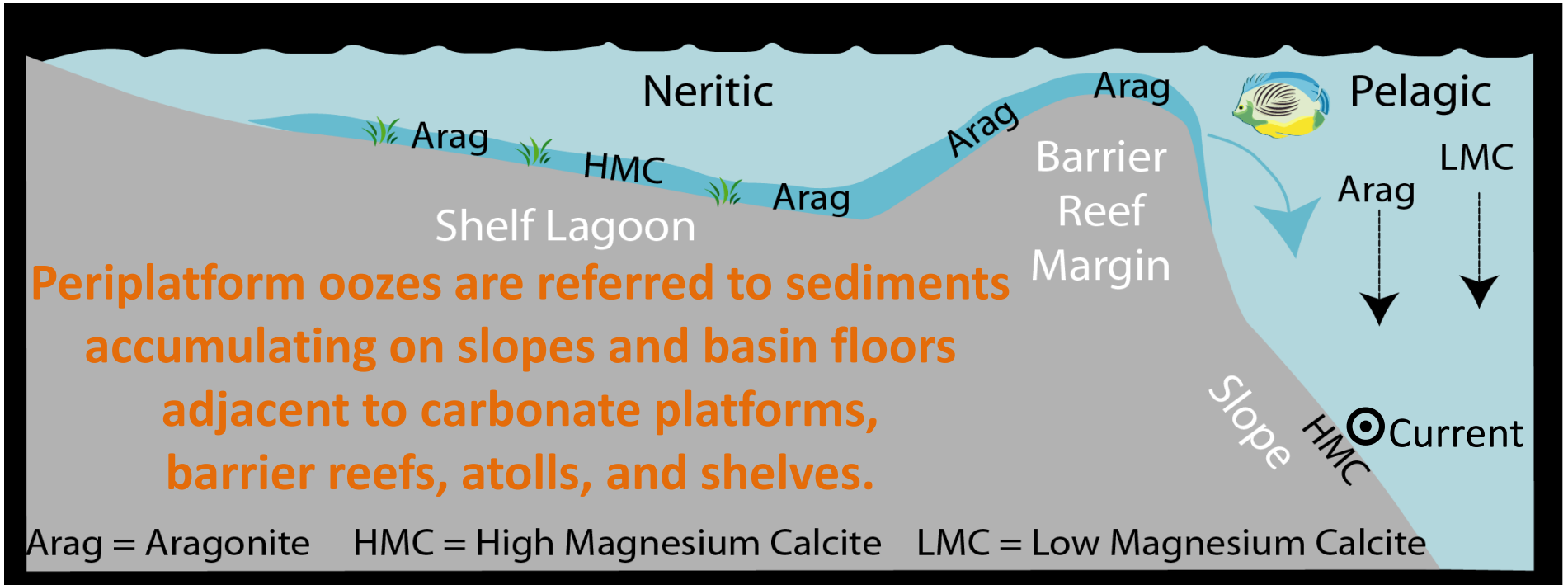
(Aragonite)

Pelagic Sources
Coccolithophores (<63 µm)
Planktic Foraminifers (LMC) (> 63 µm)
Pteropods (aragonite) (>63 µm)


(LMC)

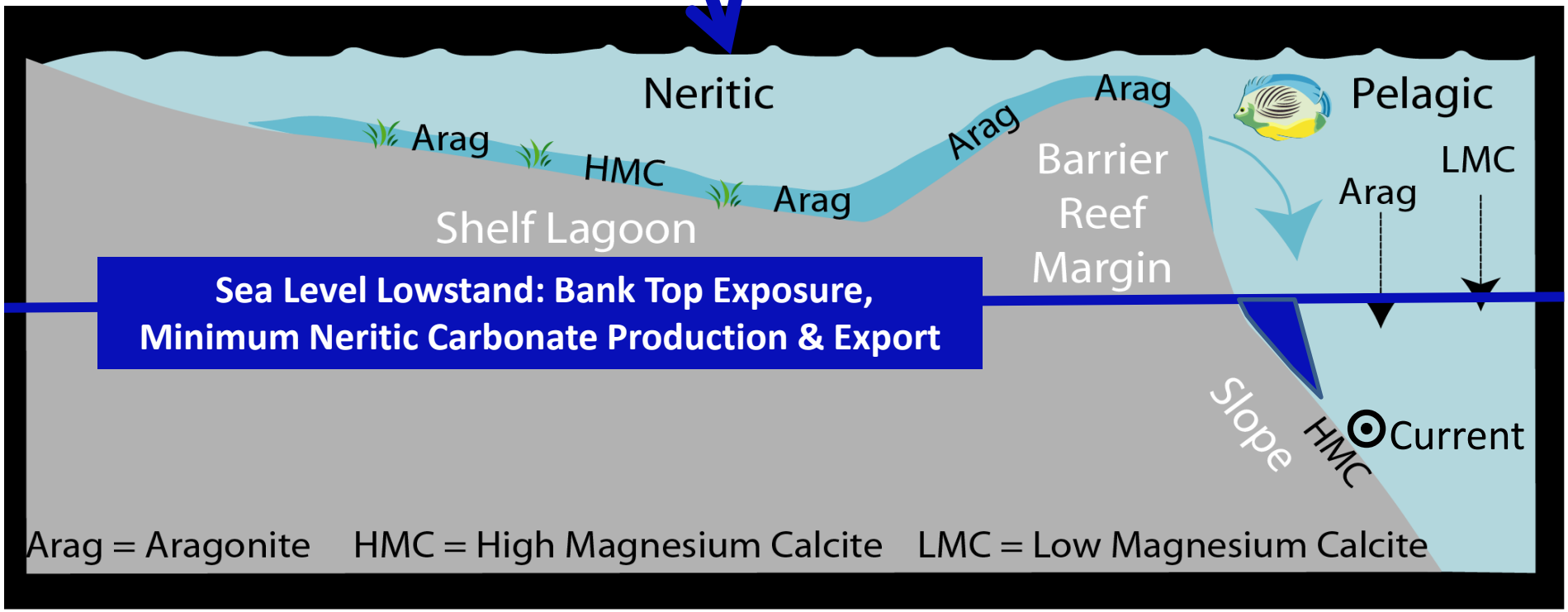
Sea Floor
Diagenesis


(HMC)



Periplatform Carbonates

Sea Level Highstand: Bank Top Flooded, Maximum Neritic Carbonate Production and Export

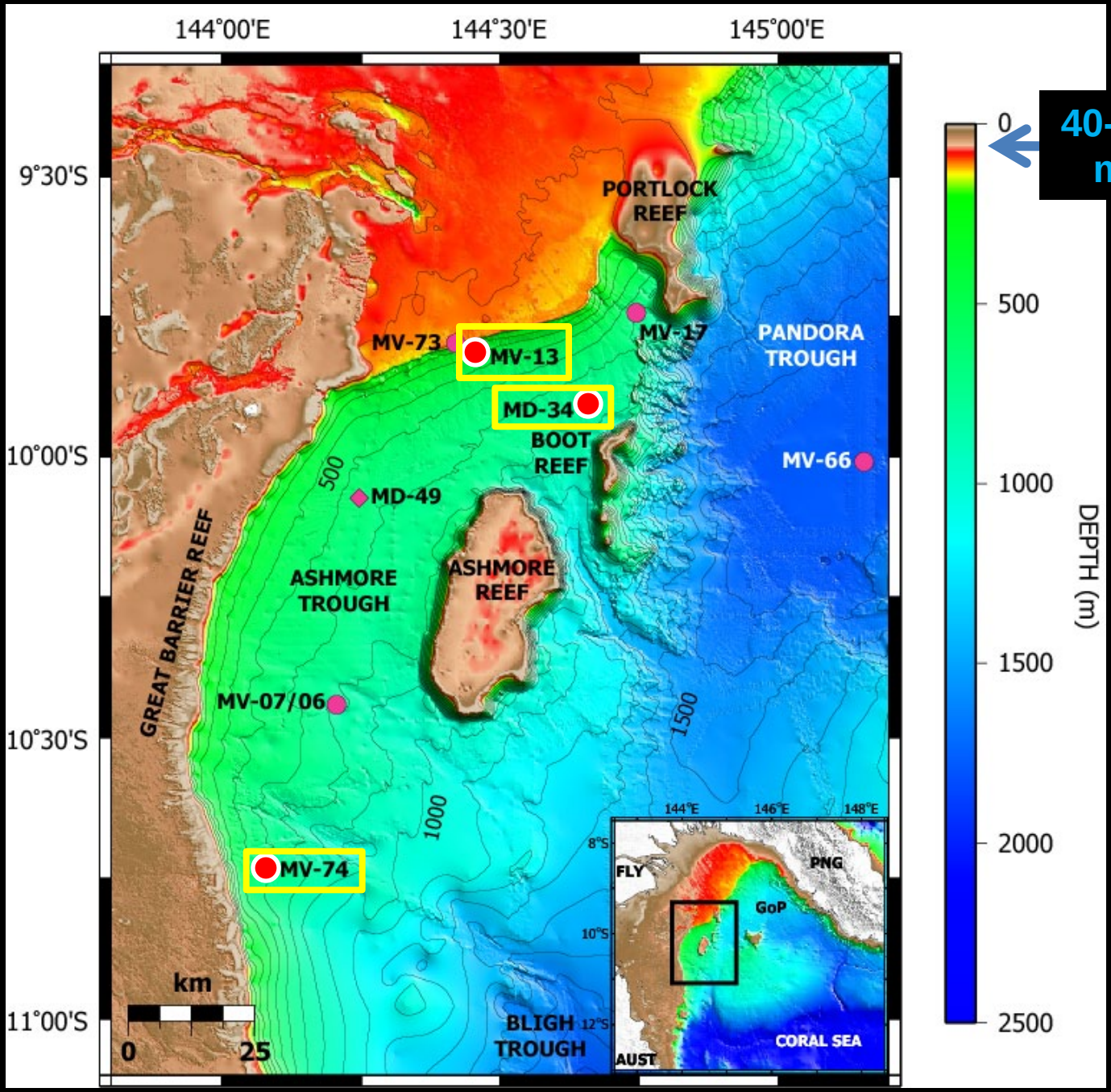


Fine Bank-Derived Aragonite, Excellent Proxy for Sea Level if the Bank Top Bathymetry is known!

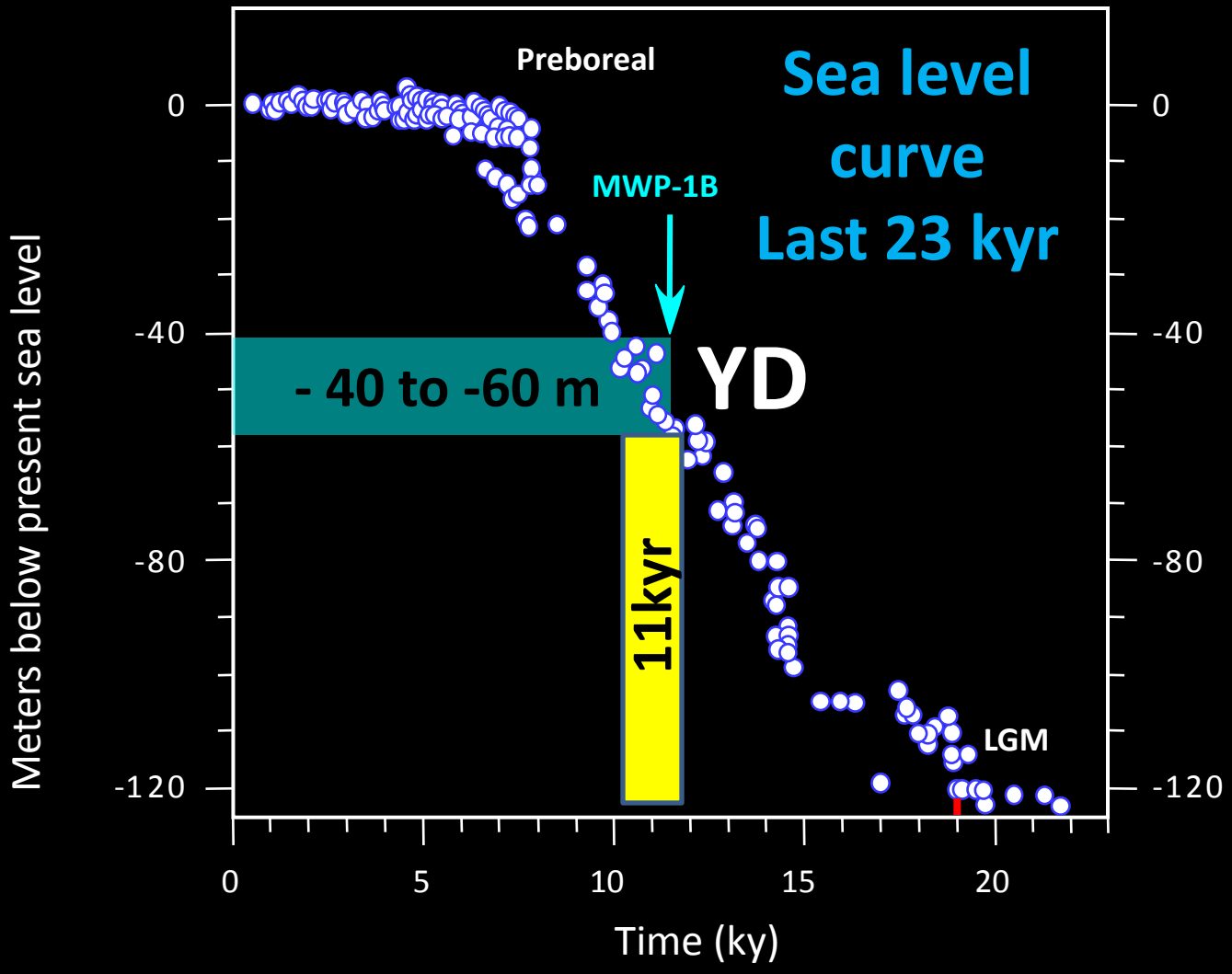
Last Deglaciation

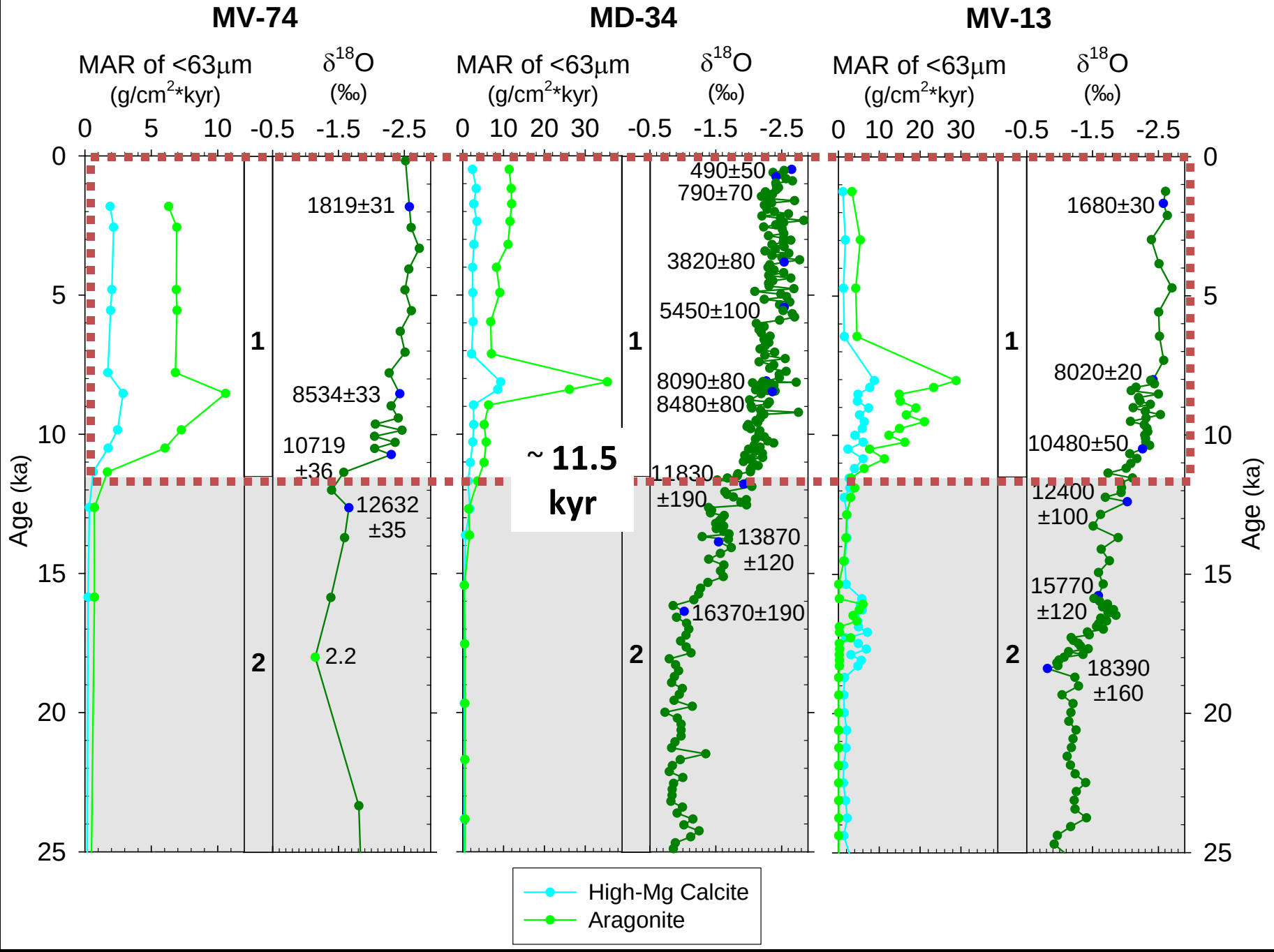
Re-Flooding Of Carbonate Factory

Average Water Depths of GBR & Offshore Atoll Lagoons 40-60 m

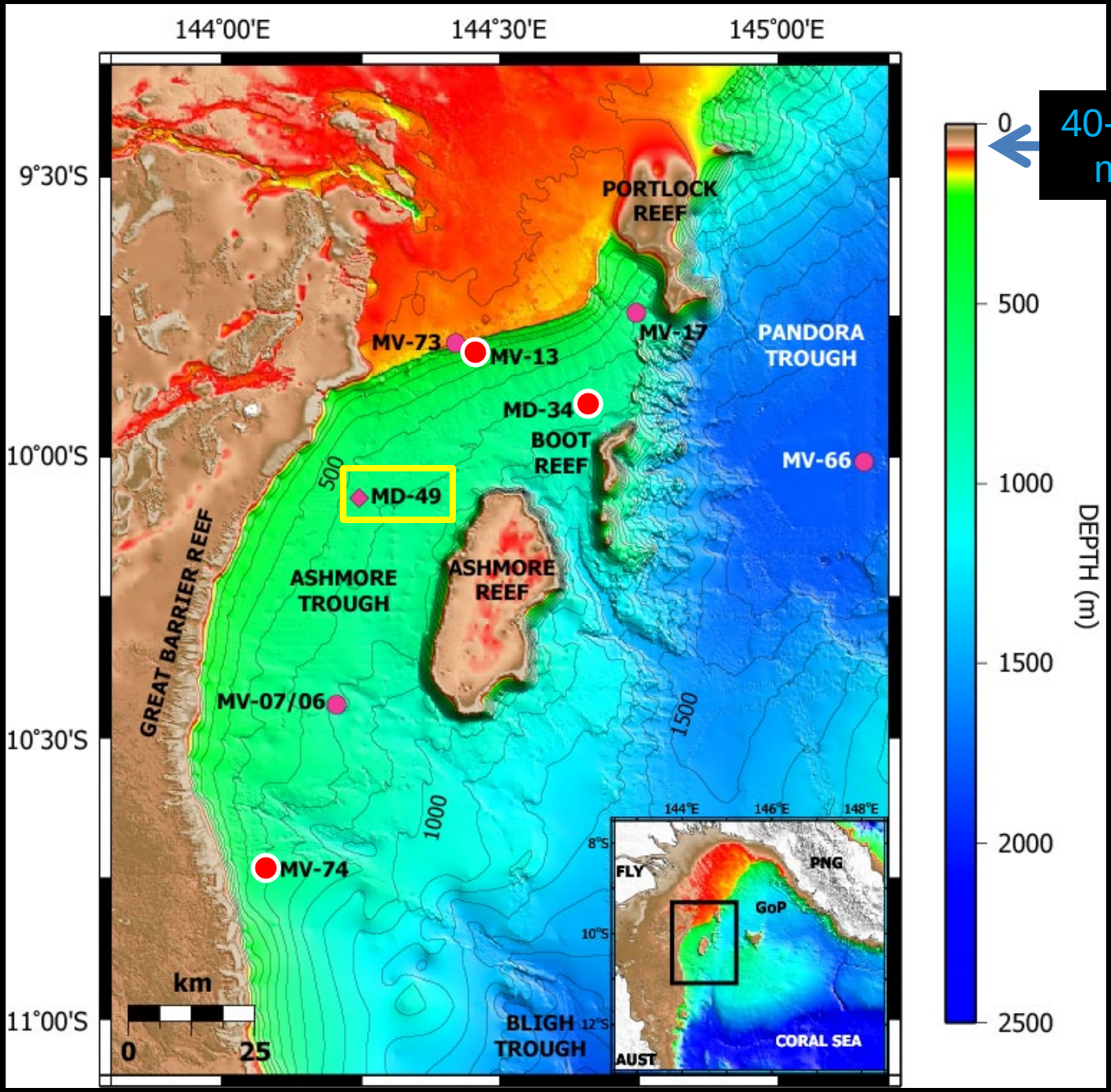


Bank/Reef Top Re-Flooding; Initiation of Neritic Carbonate Production and Export towards Adjacent Slopes

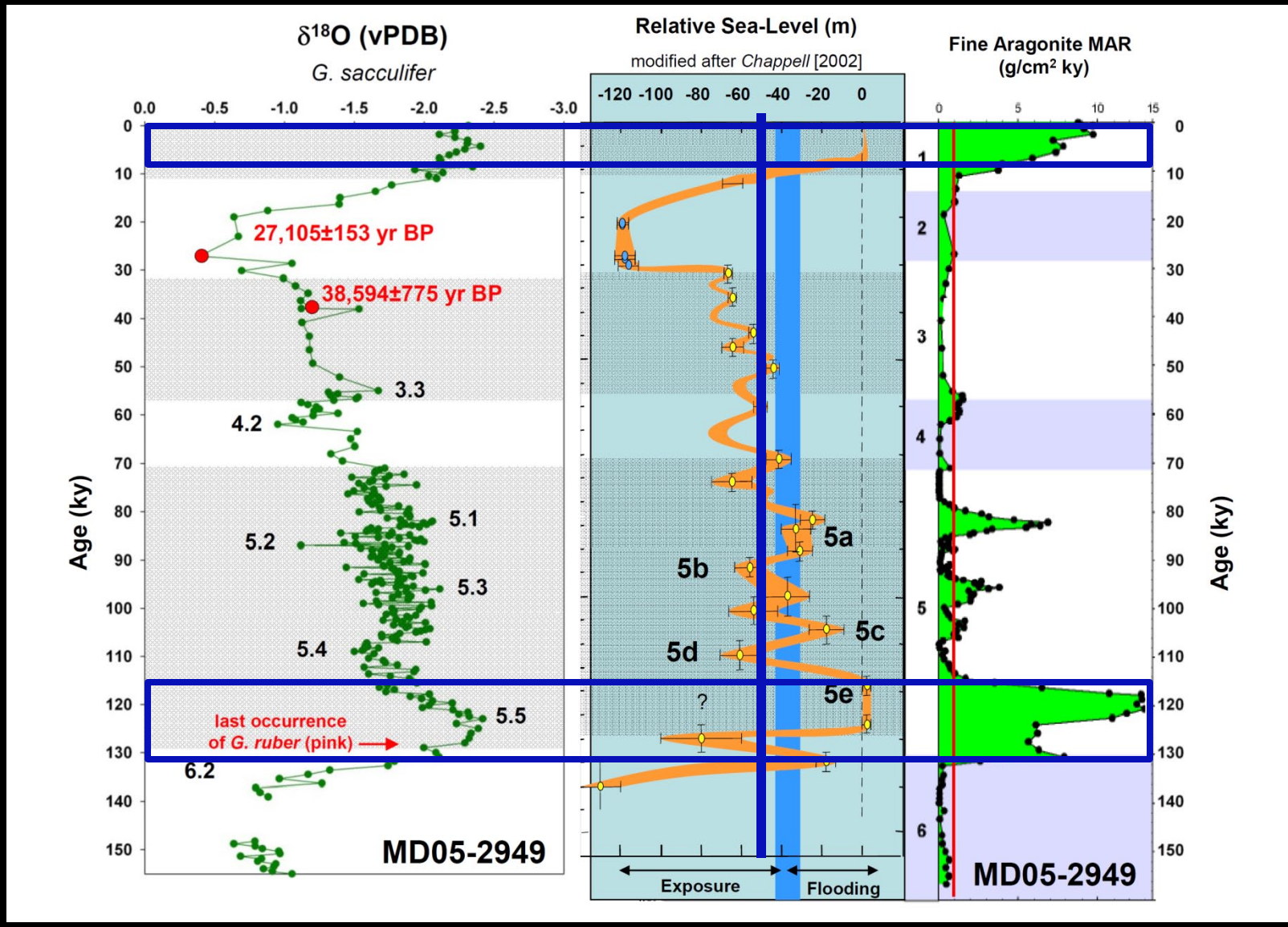



MV-74
MD-34
MV-13
MAR of <63μm
(g/cm²*kyr)
δ18O
(‰)
Age (ka)
1819±31
8534±33
10719
±36
12632
±35
2.2
490±50
790±70
3820±80
5450±100
8090±80
8480±80
11830
±190
13870
±120
16370±190
~ 11.5
kyr
1680±30
8020±20
10480±50
12400
±100
15770
±120
18390
±160
1
2
High-Mg Calcite
Aragonite

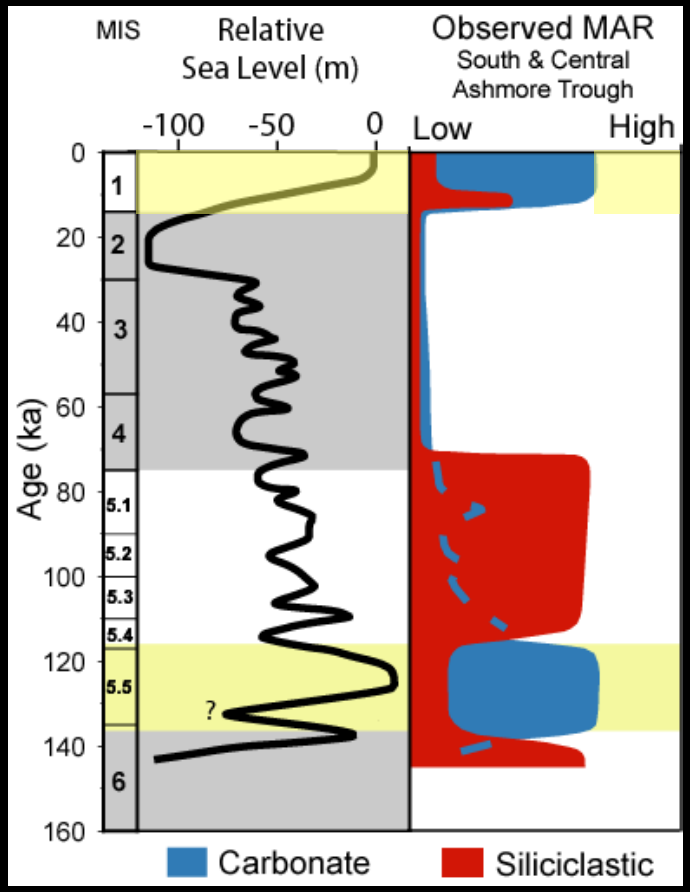
Deglacial Re-Flooding of Carbonate Factory & Highstand Neritic Export to adjacent slopes

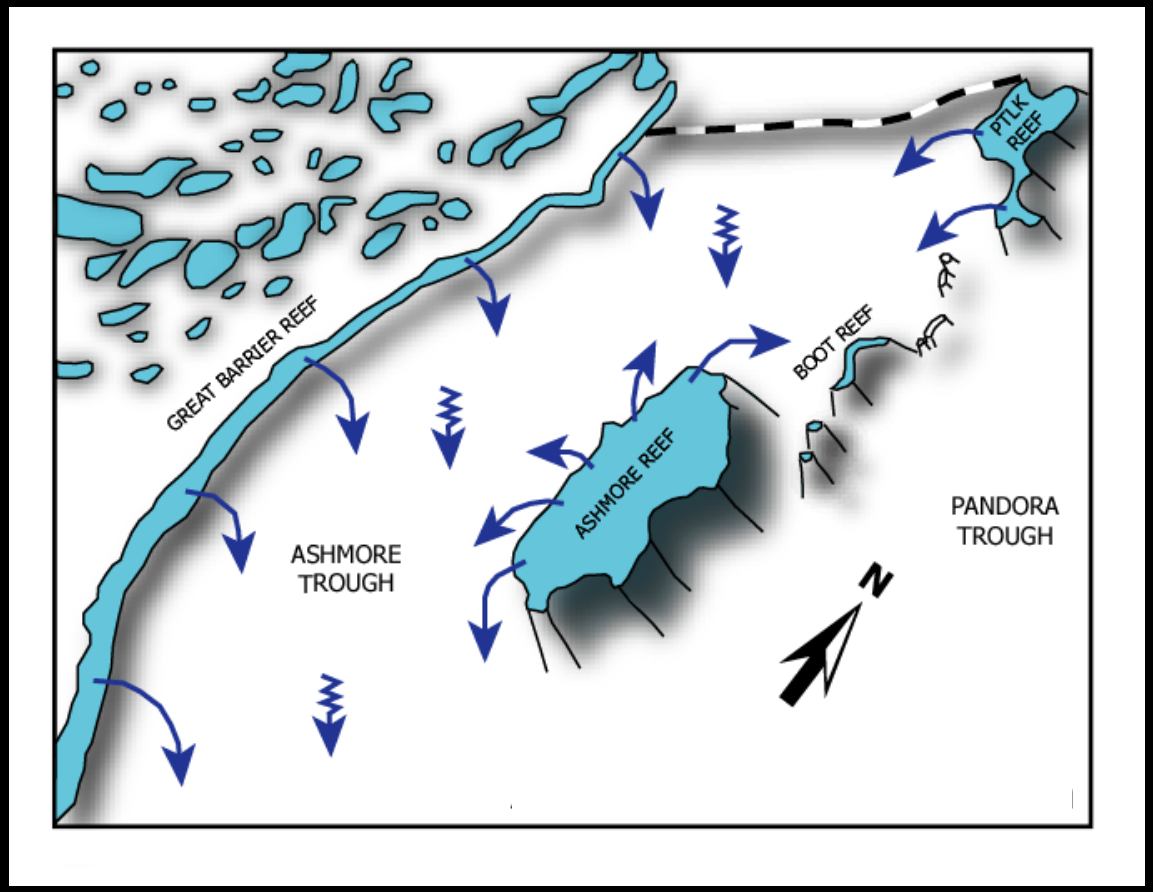


Variations of Aragonite MAR



Ashmore Trough Depositional Model





Penultimate Highstand ~130 to 115 ka
Current Interglacial Holocene < 11.5 ka

Last 150 kyr, well established Sea Level curve

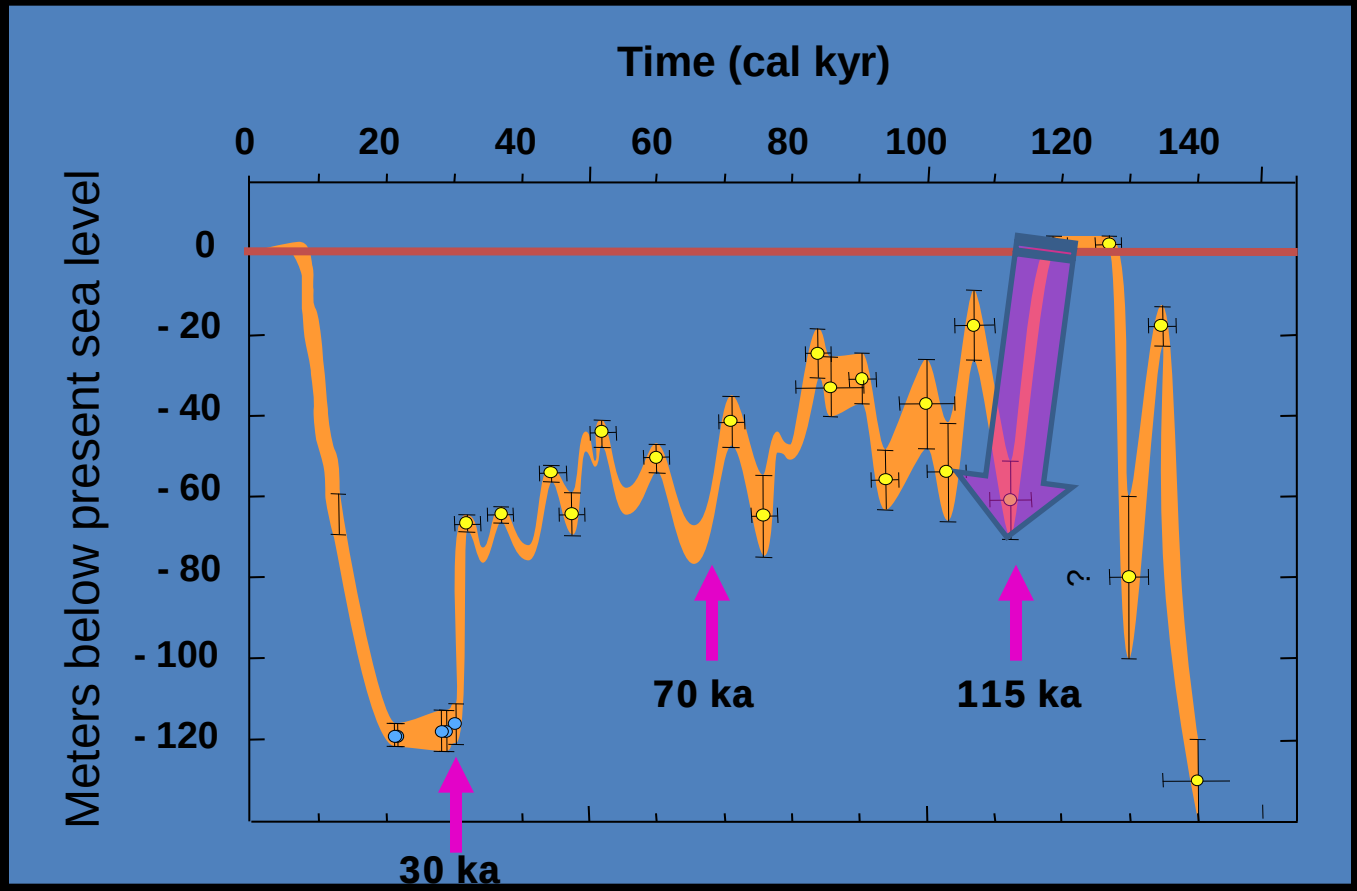
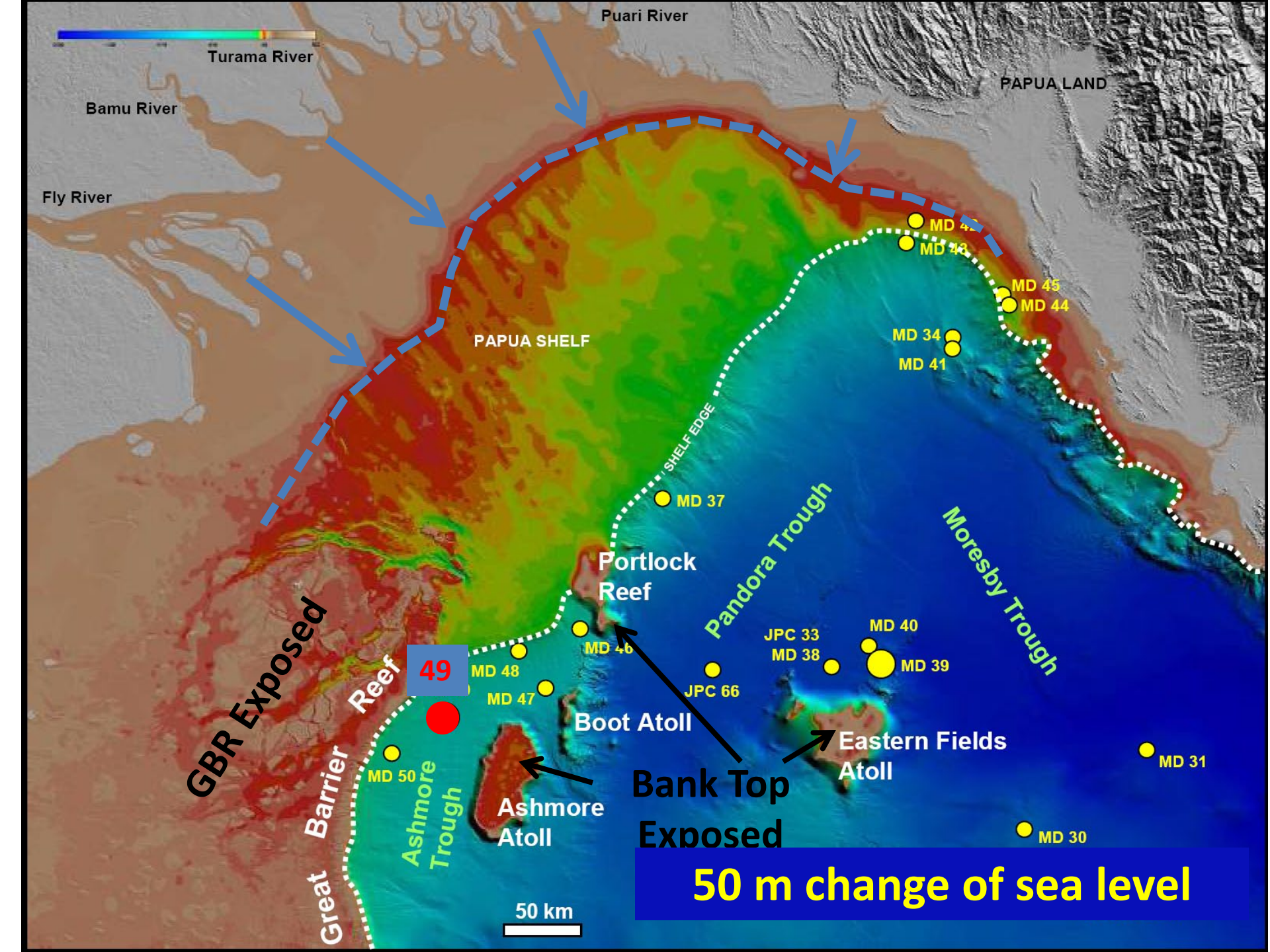
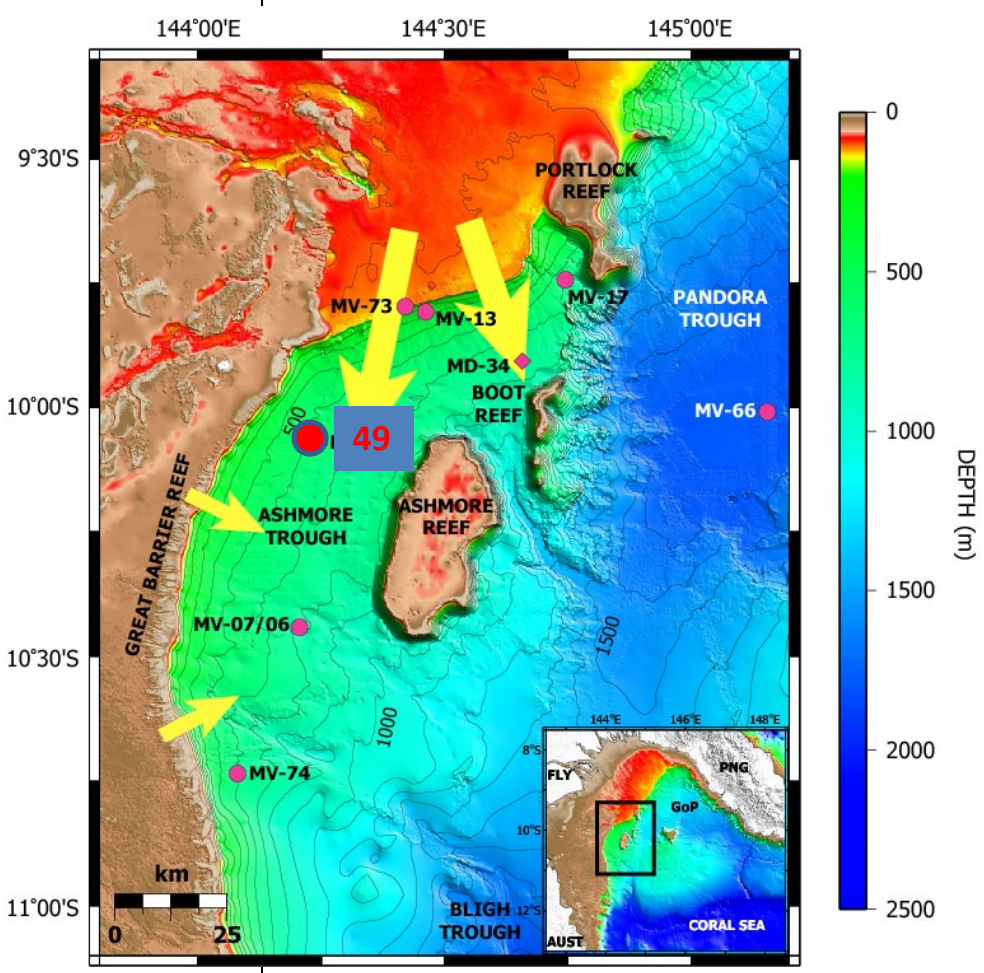
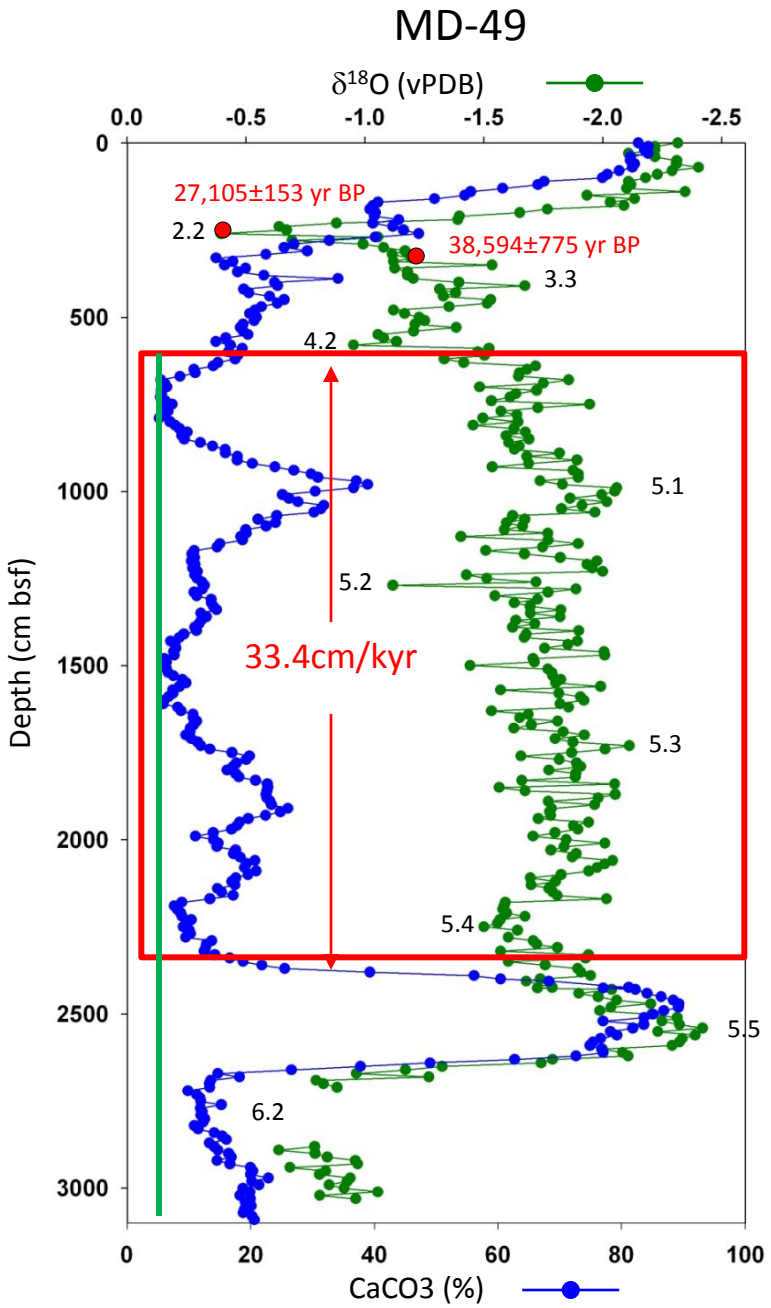


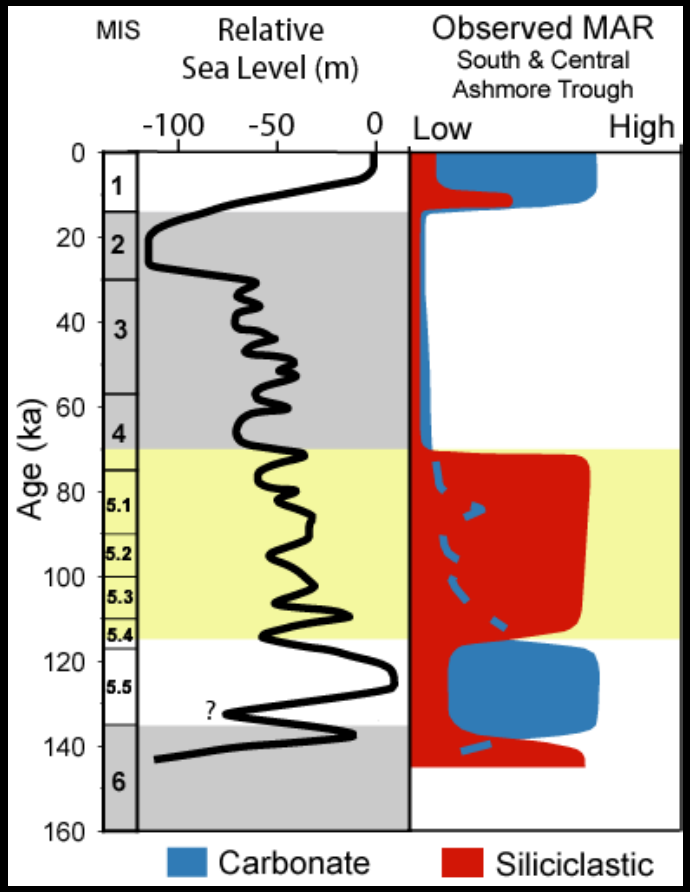
Figure from Chappell, 2002

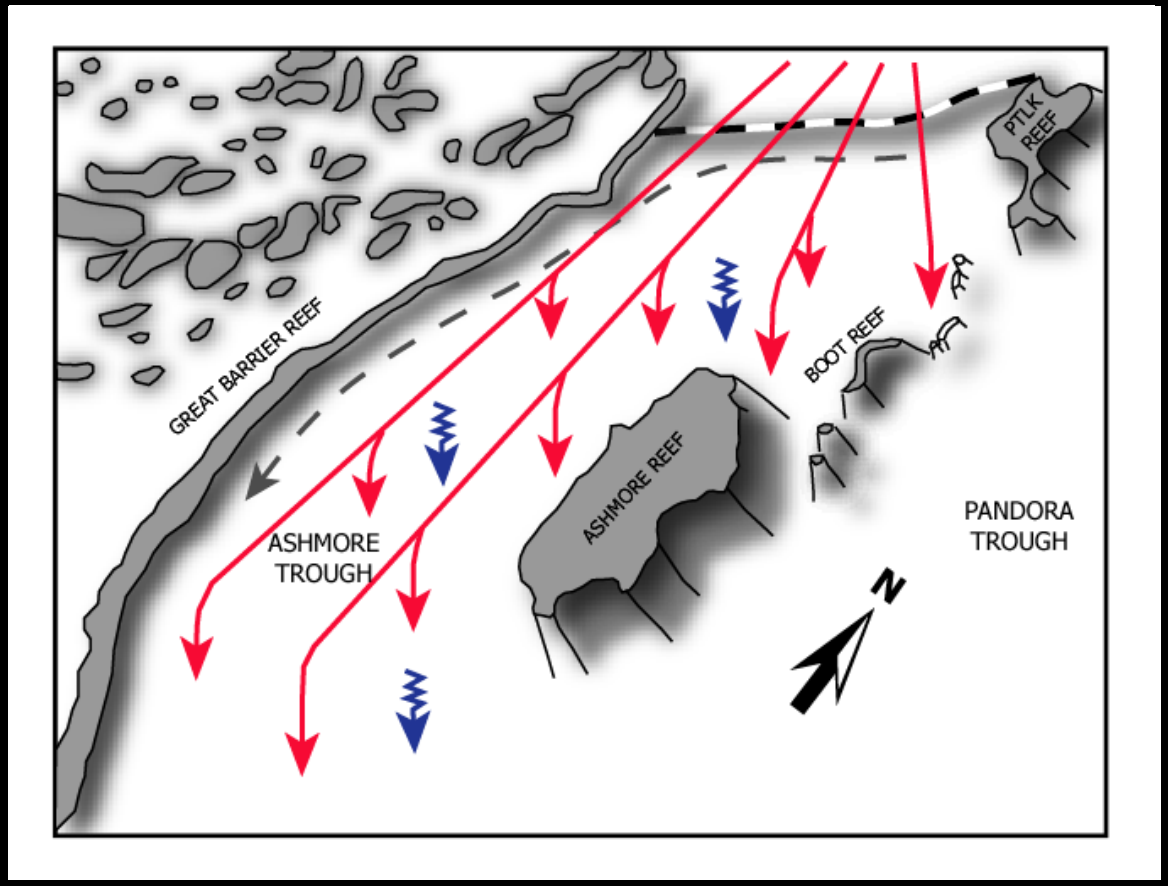

Puari River
Turama River
Bamu River
Fly River
PAPUA LAND
PAPUA SHELF
SHELF EDGE
MD 45
MD 44
MD 34
MD 41
MD 37
Portlock Reef
Pandora Trough
Moresby Trough
JPC 33
MD 38
MD 40
MD 39
JPC 66
MD 48
MD 47
MD 46
49
GBR Exposed Barrier Reef
Boot Atoll
Eastern Fields Atoll
MD 31
MD 50
Ashmore Trough
Ashmore Atoll
Bank Top Exposed
MD 30
Great
50 km
50 m change of sea level


144°00'E
144°30'E
145°00'E
9°30'S
10°00'S
10°30'S
11°00'S
PORTLOCK REEF
MV-73
MV-13
MV-17
PANDORA TROUGH
MD-34
BOOT REEF
MV-66
49
500
ASHMORE TROUGH
ASHMORE REEF
GREAT BARRIER REEF
MV-07/06
1000
1500
MV-74
km
0
25
BLIGH TROUGH
FLY
PNG
GoP
CORAL SEA
AUST
144°E
146°E
148°E
8°S
10°S
12°S
0
500
1000
1500
2000
2500
DEPTH (m)


MD-49
δ18O (vPDB)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
27,105±153 yr BP
38,594±775 yr BP
2.2
3.3
4.2
5.1
5.2
33.4cm/kyr
5.3
5.4
5.5
6.2
Depth (cm bsf)
0
500
1000
1500
2000
2500
3000
0
20
40
60
80
100
CaCO3 (%)

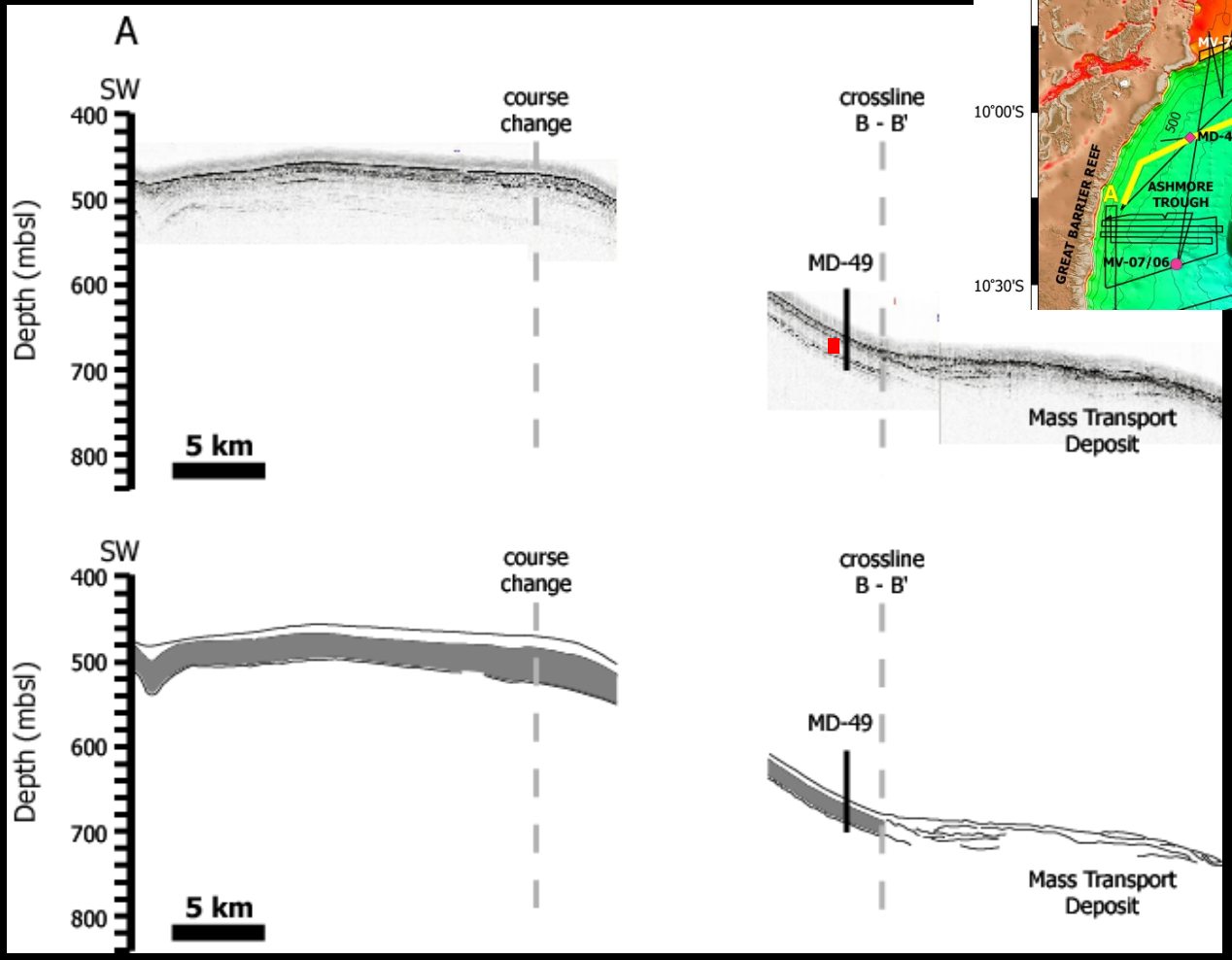
Ashmore Trough

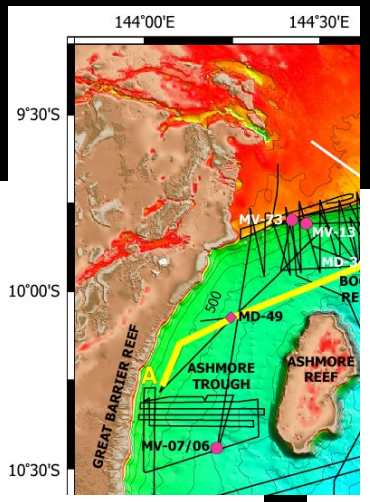


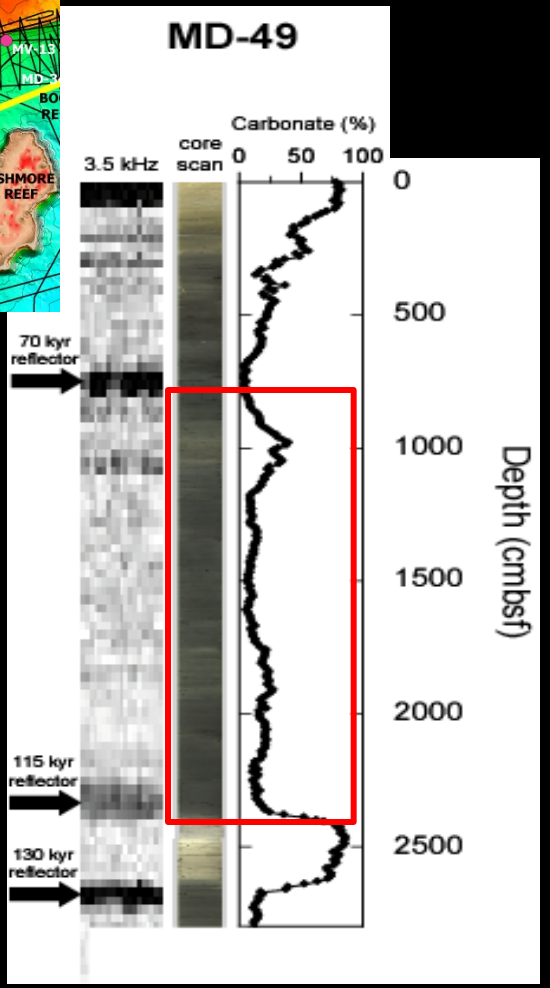


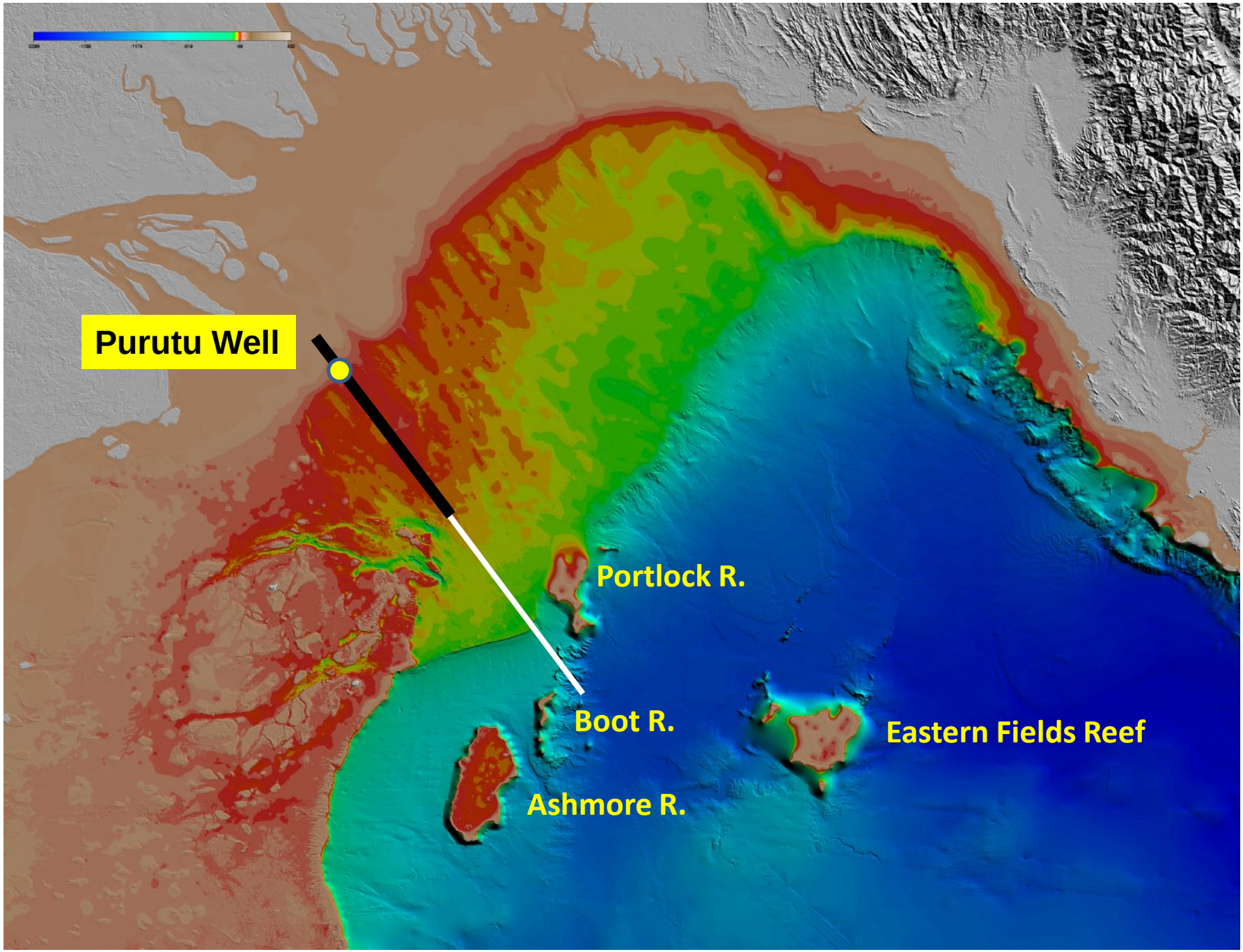
Early Sea Level Fall ~115 to 70 ka

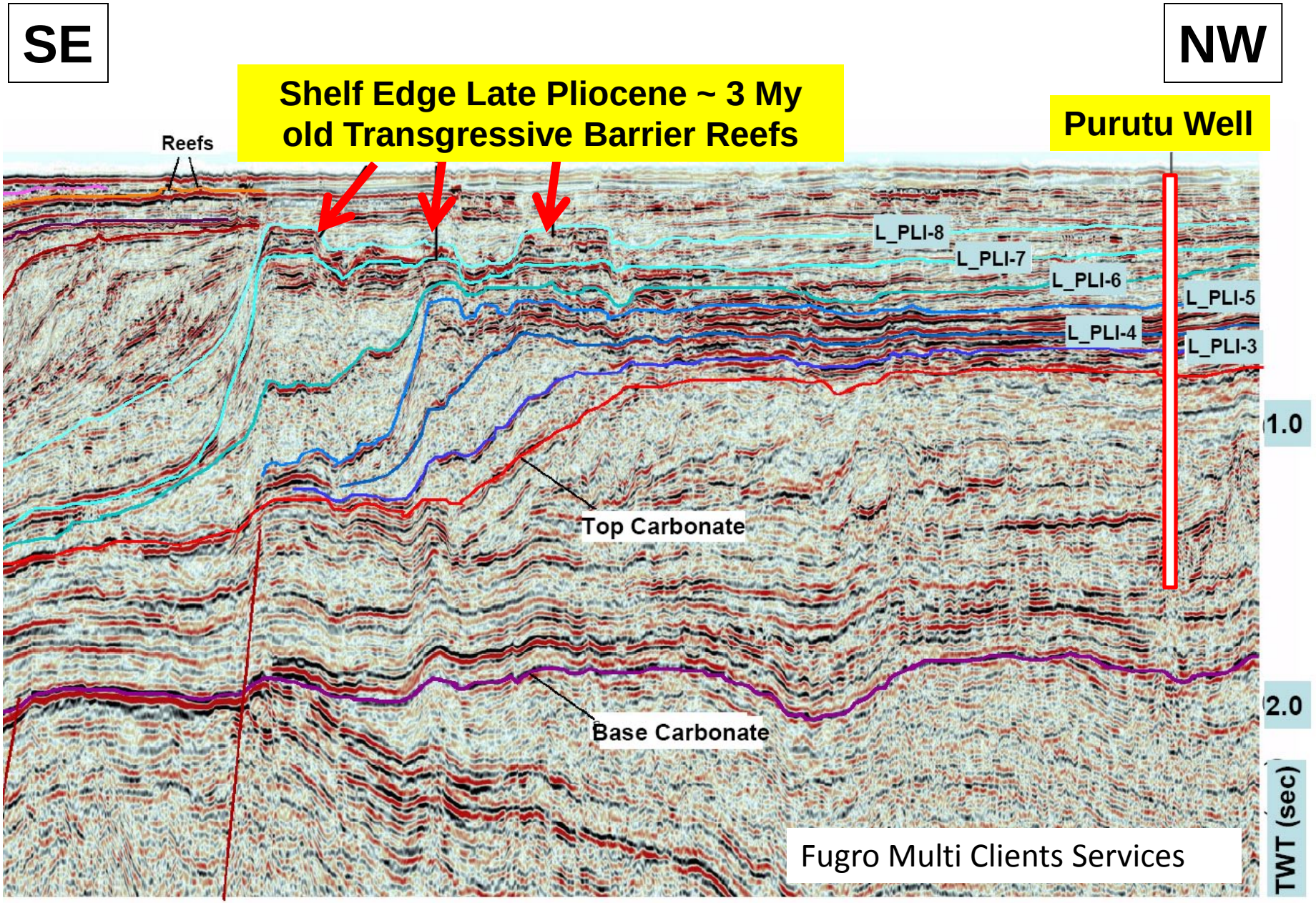
3.5 kHz seismic profile



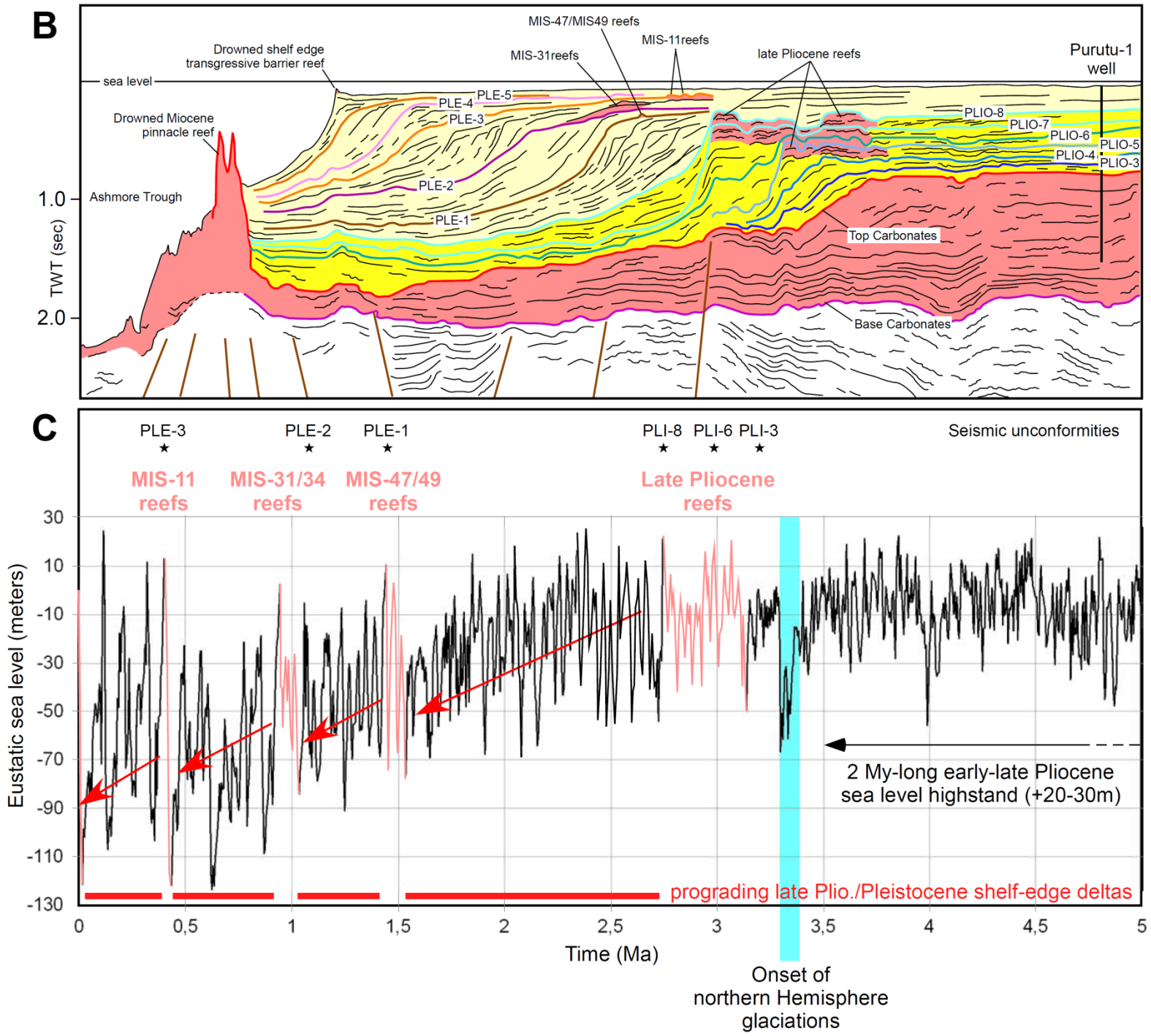




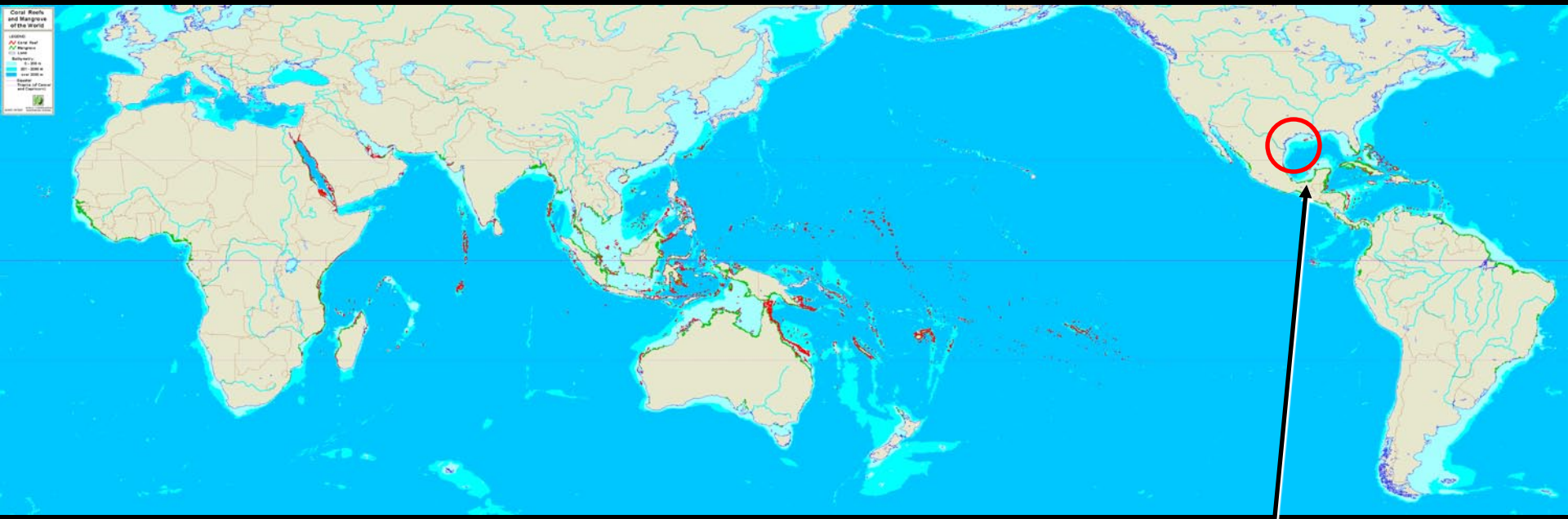

Purutu Well
Portlock R.
Boot R.
Eastern Fields Reef
Ashmore R.



Tcherepanov et al., 2009

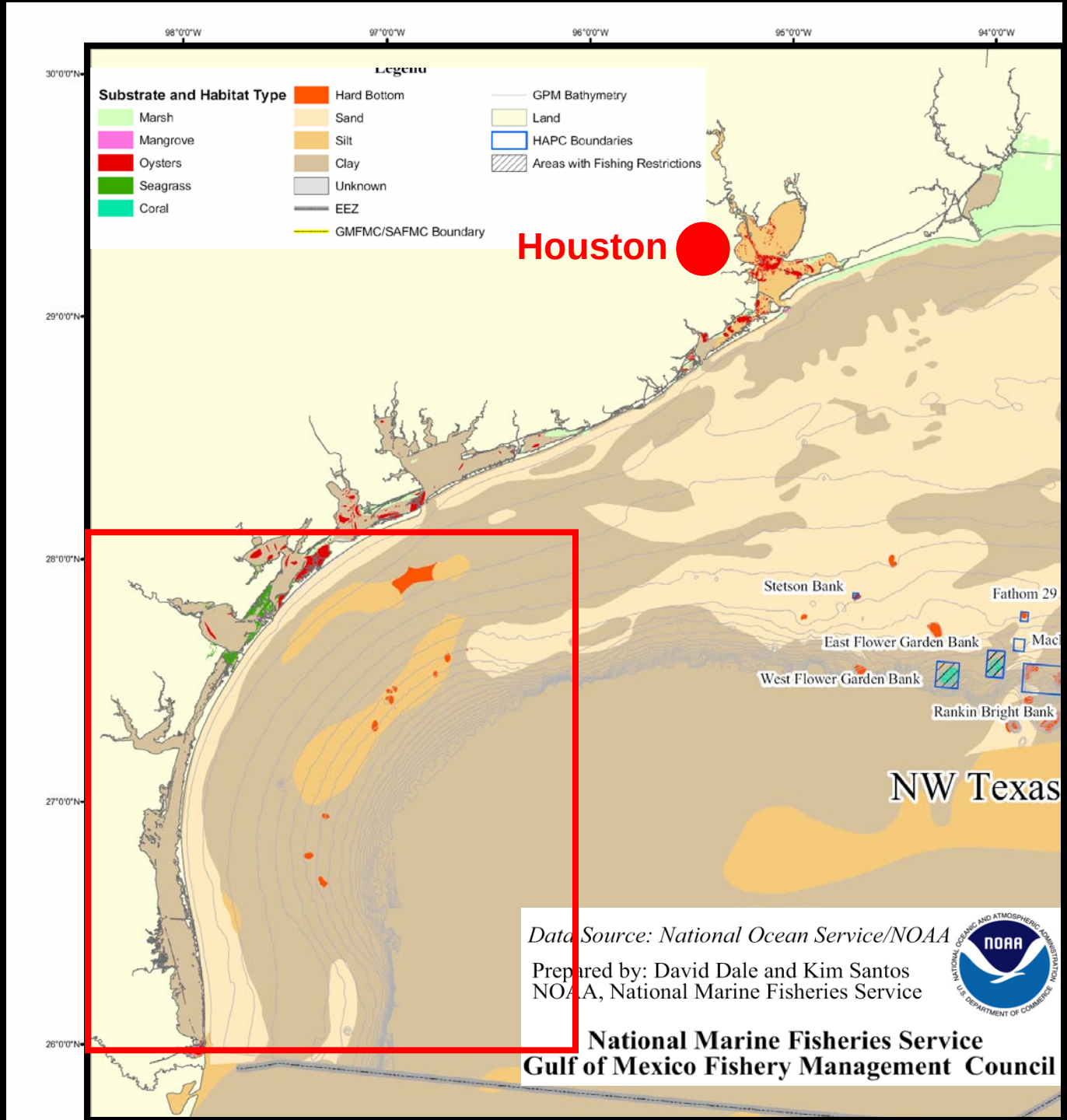

B
MIS-47/MIS49 reefs
MIS-11reefs
MIS-31reefs
late Pliocene reefs
Purutu-1 well
Drowned shelf edge transgressive barrier reef
sea level
Drowned Miocene pinnacle reef
Ashmore Trough
PLE-5
PLE-4
PLE-3
PLE-2
PLE-1
PLIO-8
PLIO-7
PLIO-6
PLIO-5
PLIO-4
PLIO-3
Top Carbonates
Base Carbonates
1.0
2.0
TWT (sec)
C
PLE-3
PLE-2
PLE-1
PLI-8
PLI-6
PLI-3
Seismic unconformities
MIS-11 reefs
MIS-31/34 reefs
MIS-47/49 reefs
Late Pliocene reefs
Eustatic sea level (meters)
30
10
-10
-30
-50
-70
-90
-110
-130
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
Time (Ma)
2 My-long early-late Pliocene sea level highstand (+20-30m)
prograding late Plio./Pleistocene shelf-edge deltas
Onset of northern Hemisphere glaciations

Mixed Cabonate Siliciclastic Sedimentary Systems in Low Latitudes

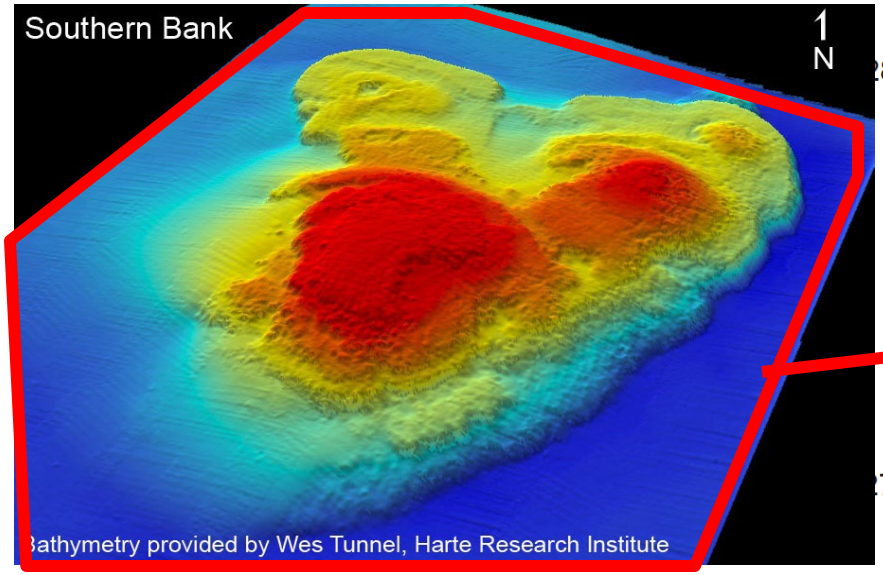


Western Texas Shelf

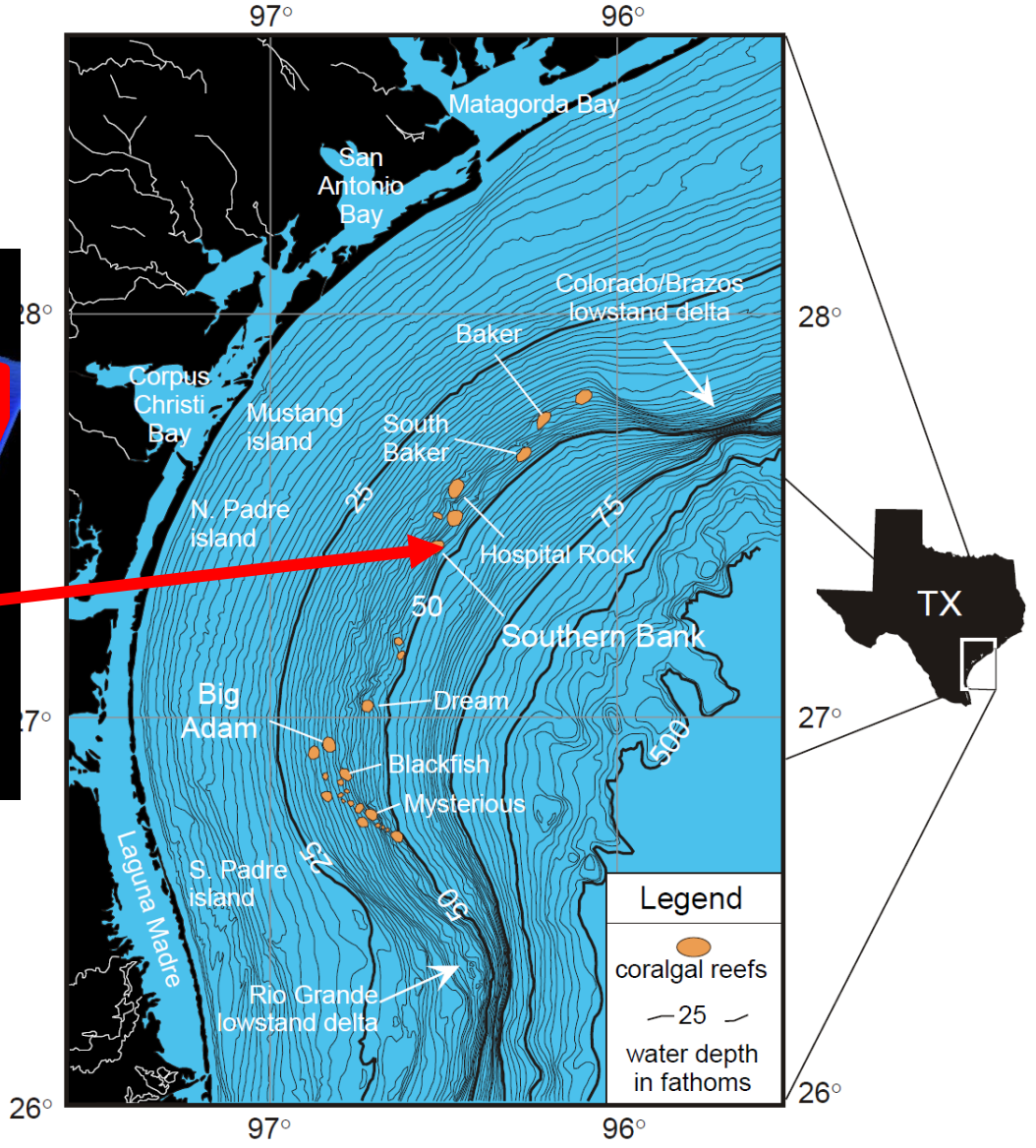
Source of global reef map: http://www.wcmc.org.uk/marine/data/coral_mangrove/marine.maps.main.html

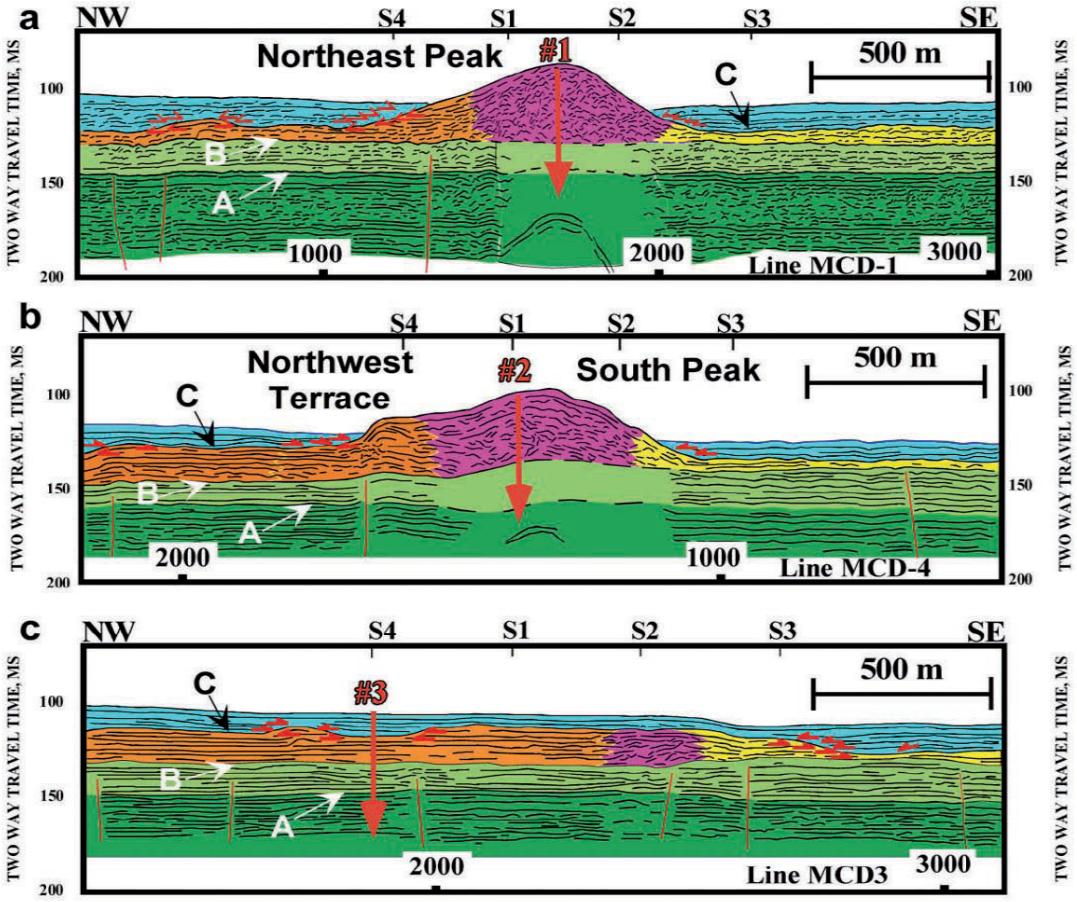


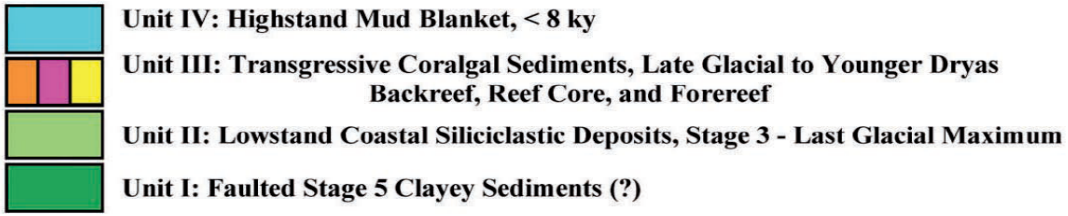
South Texas Shelf Edge Drowned Coralgal Banks

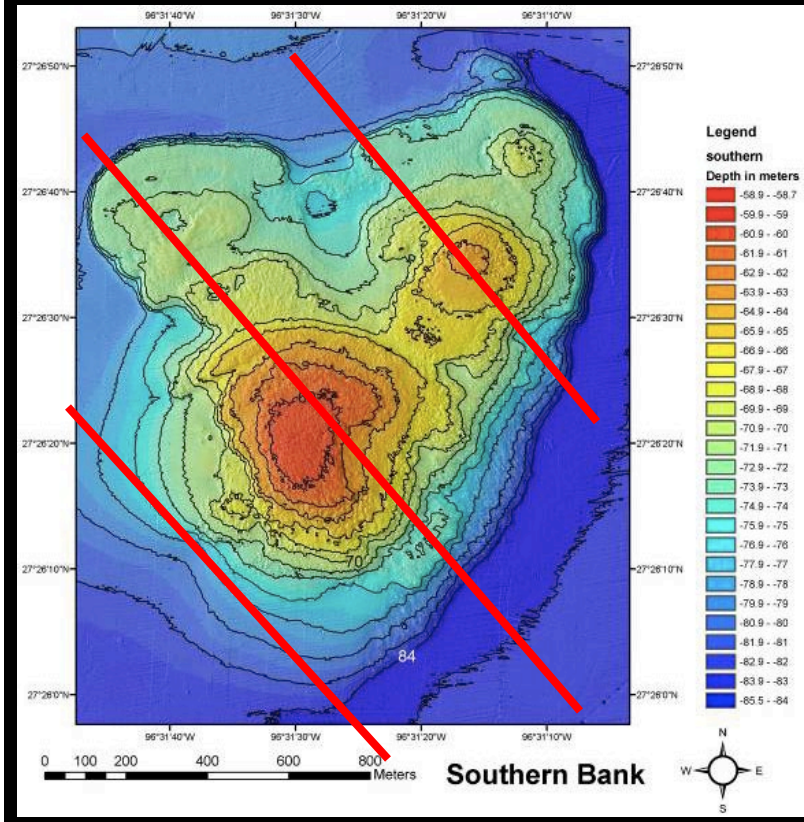


High : -58.840000
meters below sea-level
Low : -85.320000

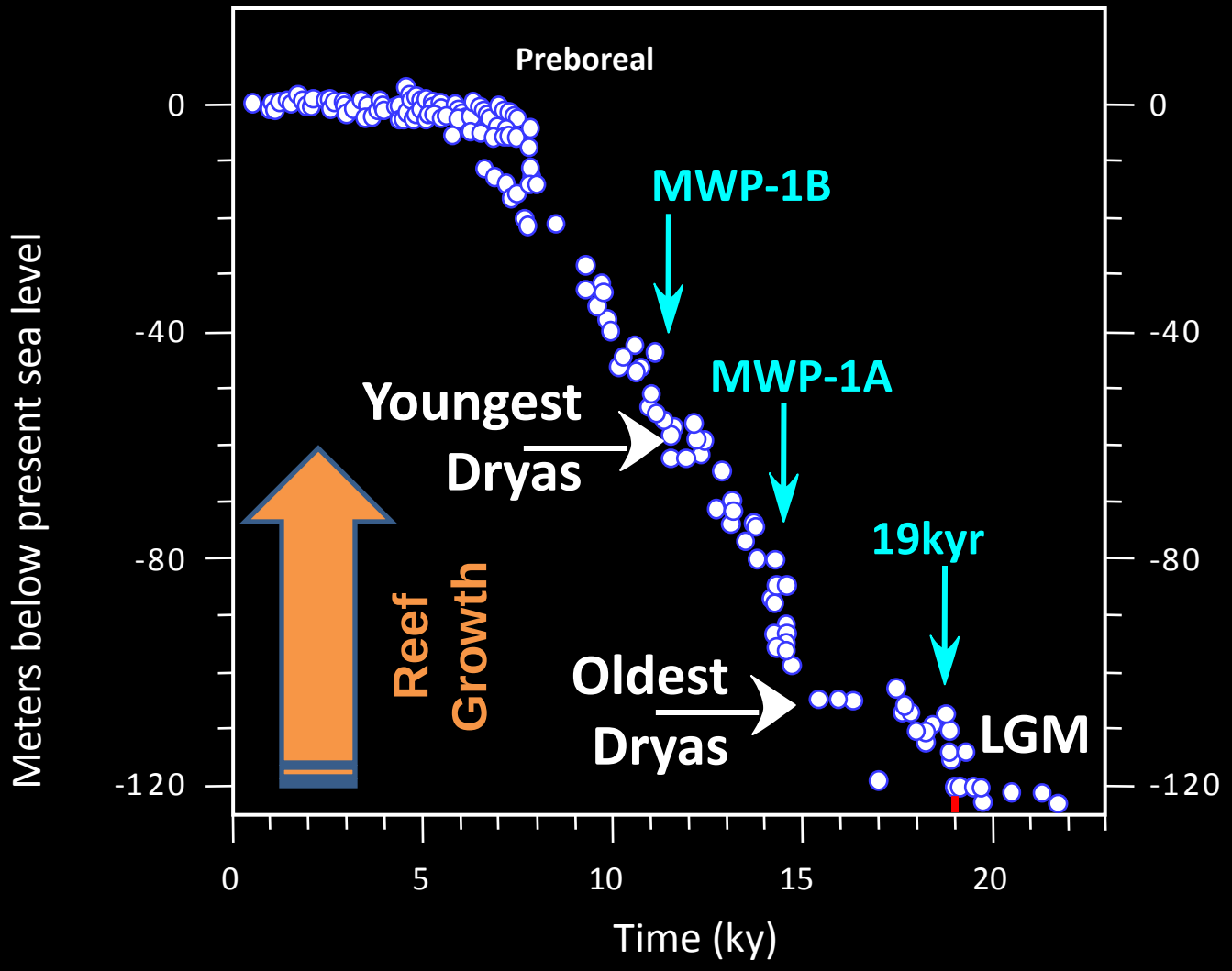



a
NW
S4
S1
S2
S3
SE
Northeast Peak
#1
500 m
C
B
A
1000
2000
3000
Line MCD-1
TWO WAY TRAVEL TIME, MS
100
150
200
b
Northwest Terrace
#2
South Peak
Line MCD-4
c
#3
2000
Line MCD3

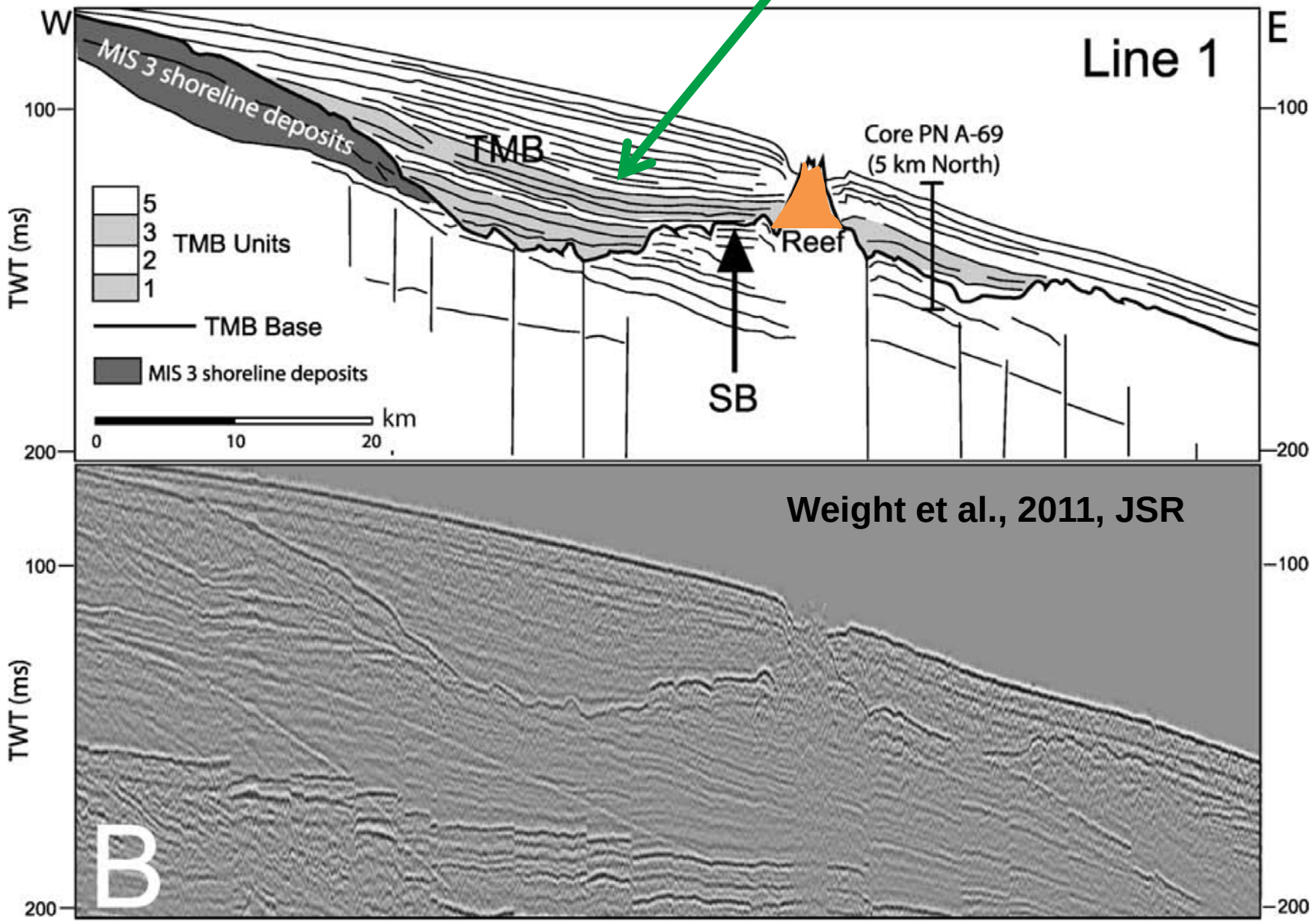

Unit IV: Highstand Mud Blanket, < 8 ky
Unit III: Transgressive Coralgal Sediments, Late Glacial to Younger Dryas Backreef, Reef Core, and Forereef
Unit II: Lowstand Coastal Siliciclastic Deposits, Stage 3 - Last Glacial Maximum
Unit I: Faulted Stage 5 Clayey Sediments (?)


Legend
southern
Depth in meters
-58.9 - -58.7
-59.9 - -59
-60.9 - -60
-61.9 - -61
-62.9 - -62
-63.9 - -63
-64.9 - -64
-65.9 - -65
-66.9 - -66
-67.9 - -67
-68.9 - -68
-69.9 - -69
-70.9 - -70
-71.9 - -71
-72.9 - -72
-73.9 - -73
-74.9 - -74
-75.9 - -75
-76.9 - -76
-77.9 - -77
-78.9 - -78
-79.9 - -79
-80.9 - -80
-81.9 - -81
-82.9 - -82
-83.9 - -83
-85.5 - -84
96°31'40"W
96°31'30"W
96°31'20"W
96°31'10"W
27°26'50"N
27°26'40"N
27°26'30"N
27°26'20"N
27°26'10"N
27°26'0"N
0 100 200 400 600 800
Meters
Southern Bank
N
W
E
S

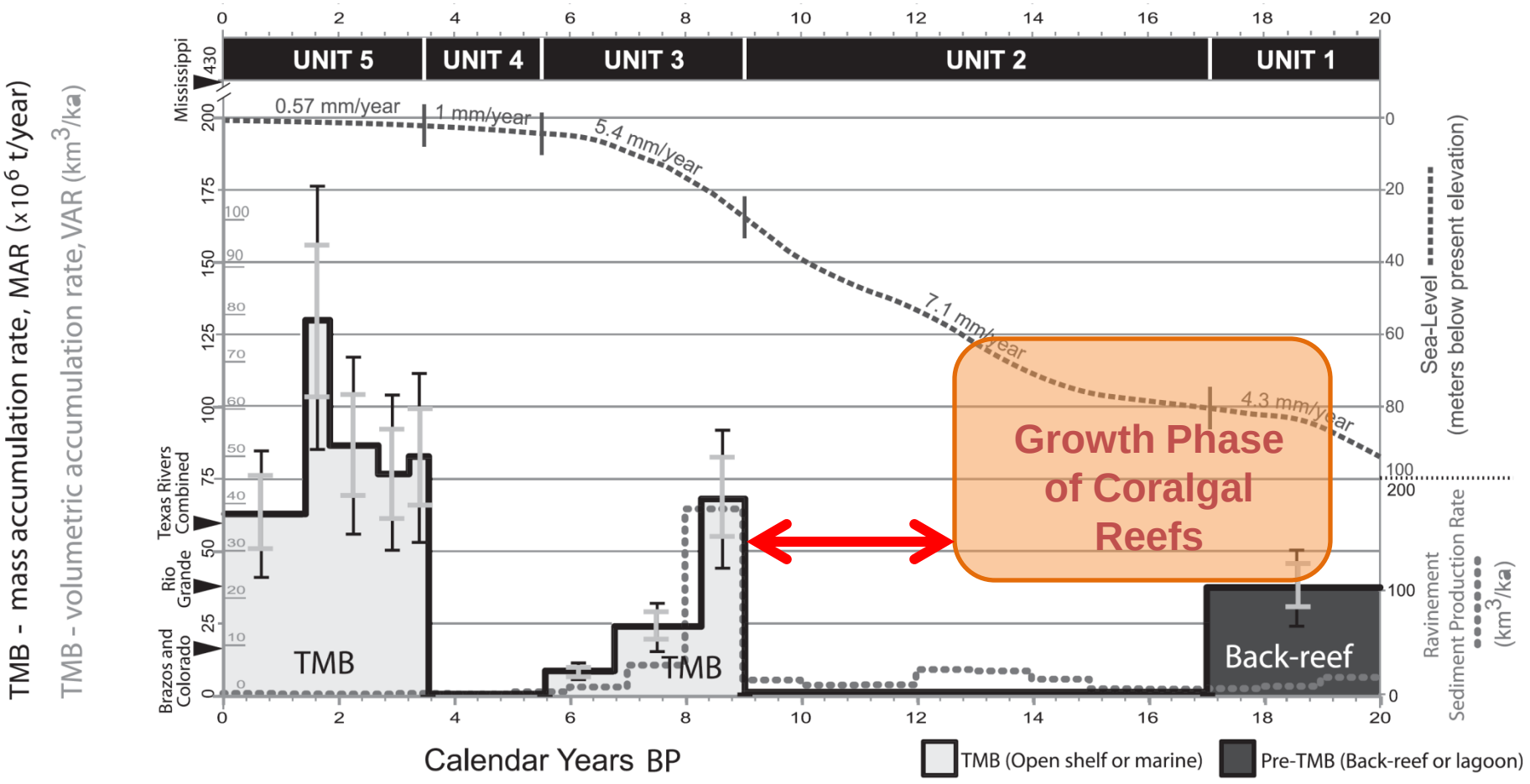
Sea Level Variations since Last Glacial Maximum



Texas Shelf Mud Blanket



Texas Shelf Mud Blanket
Variations of Accumulation in the past 20 kyr



Weight et al., 2011, JSR

Take Home Message:
Mixed Systems along Low Latitude Continental Margins

Early Sea Level Rise / Deglaciation: a "Window of Opportunity" for the Reef Establishment on top of Lowstand Coastal Siliciclastic Deposits such as Elongated Barrier Islands, Linear Beach Ridges

Sea Level Highstands: Maximum neritic carbonate shedding on adjacent slopes and basins
Initial burial of shelf edge drowned reefs by siliciclastic muds

Early Sea Level Fall: Thick wedges of siliciclastic mud plastered on the upper slopes in front of exposed barrier reefs

Thank You for your attention!