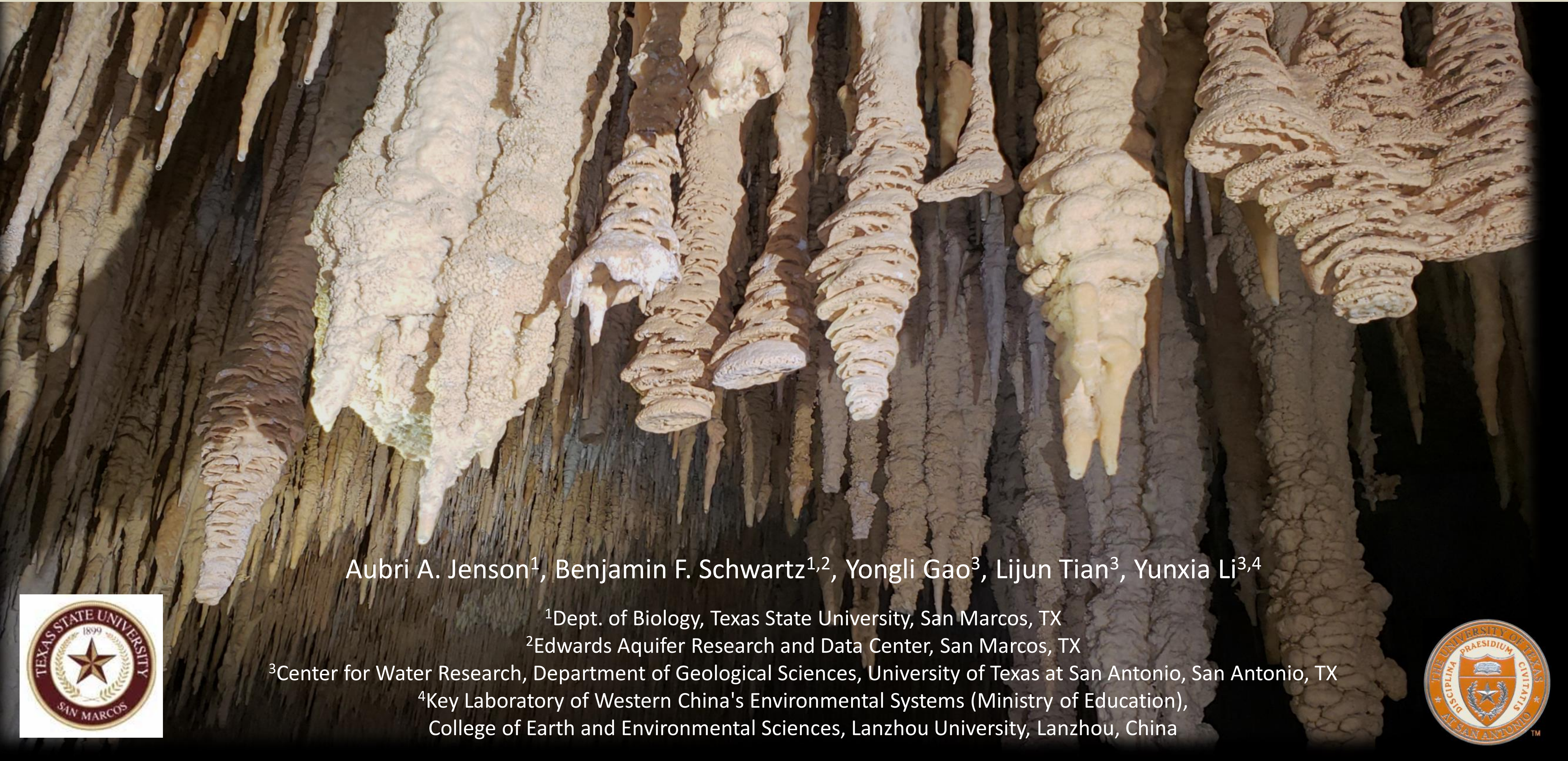
The implications and limitations of Phreatic Overgrowths of Speleothems as indicators of Sea Level: Quintana Roo, Mexico



Aubri A. Jenson[1], Benjamin F. Schwartz[1,2], Yongli Gao[3], Lijun Tian[3], Yunxia Li[3,4]

[1]Dept. of Biology, Texas State University, San Marcos, TX
[2]Edwards Aquifer Research and Data Center, San Marcos, TX
[3]Center for Water Research, Department of Geological Sciences, University of Texas at San Antonio, San Antonio, TX
[4]Key Laboratory of Western China's Environmental Systems (Ministry of Education),
College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, China

Overview

Geologic History of Quintana Roo, Mexico

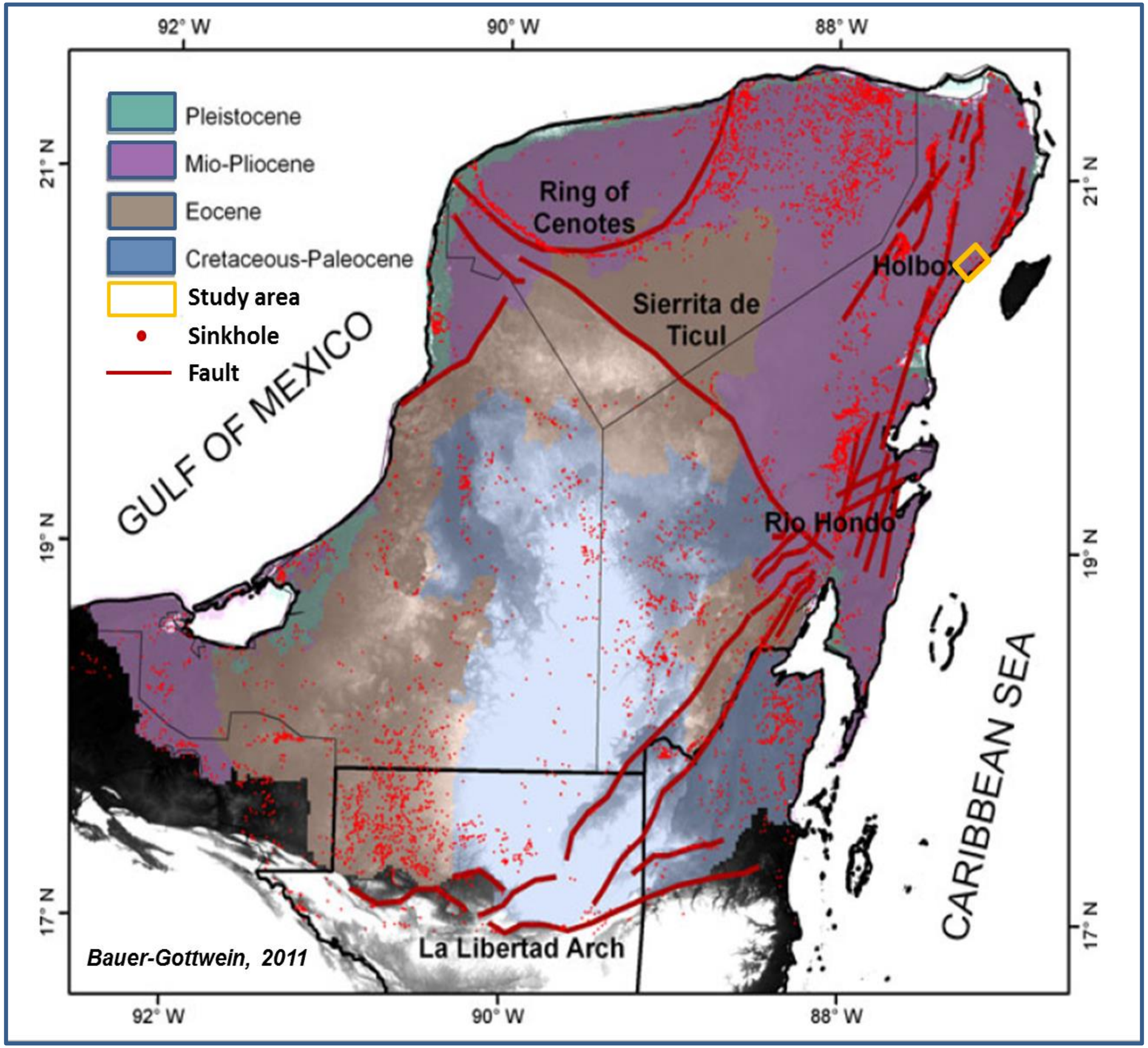
Research Framework

U-Th Analysis of
Phreatic Overgrowths of Speleothems

Limitations and Sources of Uncertainty

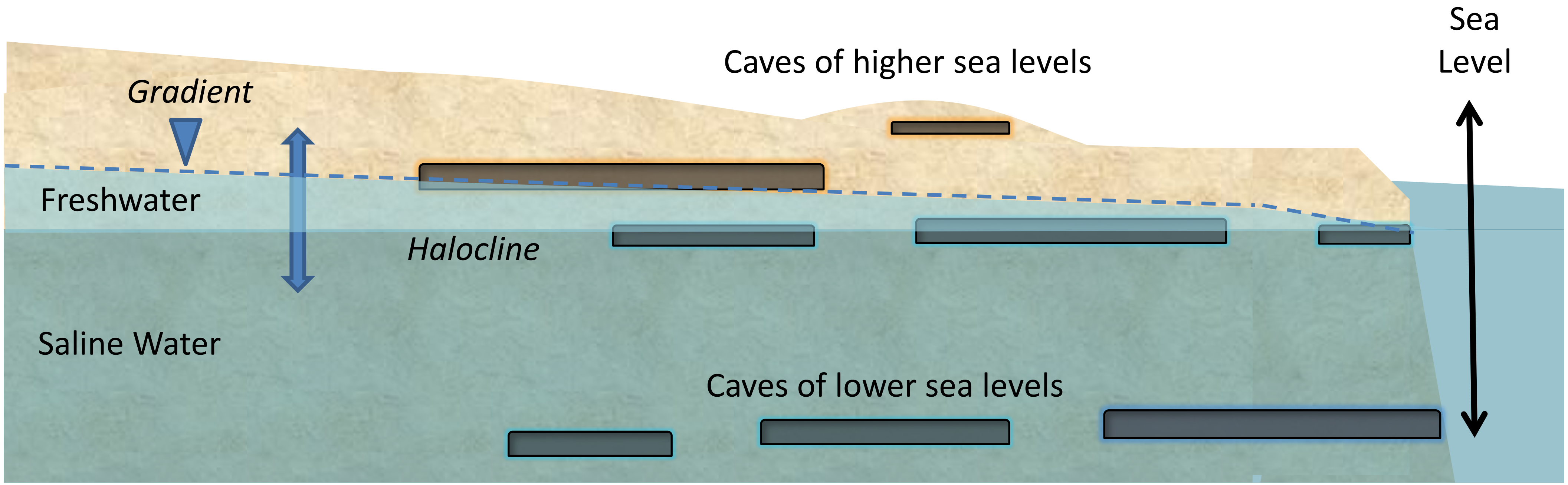
Implications for Sea Level and Tectonic History


N
200 km
Gulf of
Mexico
Caribbean
Sea
Yucatan
Peninsula
Study Site
Progreso
Mérida
Tizimín
Cancún
Playa del
Carmen
Valladolid
Uxmal
YUCATAN
Tulum
Campeche
Champoton
CAMPECHE
QUINTANA
ROO
Ciudad del
Carmen
Escárcega
Reserva de
la Biósfera
Calakmul
Mahahual
Bacalar
Chetumal
TABASCO
San Pedro
Palenque
Tenosique
Reserva de
Biosfera Maya
Belize City
Belmopan
Parque Natural
Montes Azules
Belize
Comitán
Area shown
From Google Maps, 2018



92° W
90° W
88° W
21° N
19° N
17° N
Pleistocene
Mio-Pliocene
Eocene
Cretaceous-Paleocene
Study area
Sinkhole
Fault
GULF OF MEXICO
CARIBBEAN SEA
Ring of Cenotes
Sierrita de Ticul
Holbox
Rio Hondo
La Libertad Arch
Bauer-Gottwein, 2011

Coastal Karst Conceptual Model



- Freshwater lies on denser saltwater
- Mixing results in undersaturation with respect to calcite
- Most aggressive conduit development occurs along halocline
- Cave elevations should correspond to changing sea levels over time

- The Halocline is often sharp, which reduces mixing
- Wall notches should indicate past sea level stands
- Dissolution may be slower than modeled, as evident by columns

Underwater caves in Quintana Roo: 1,400 km mapped since 1970's

- Depth of 0-20 m below sea level; thought to be forming today at halocline

- Laterally extensive, flat floors and ceilings consistent with dissolution along halocline and/or bedding planes

- Most work has focused on these caves for recent climate history

Dry caves in Quintana Roo: 260 km mapped since 2000’s

- Depth of 0-20 m above sea level, shallow with frequent collapse

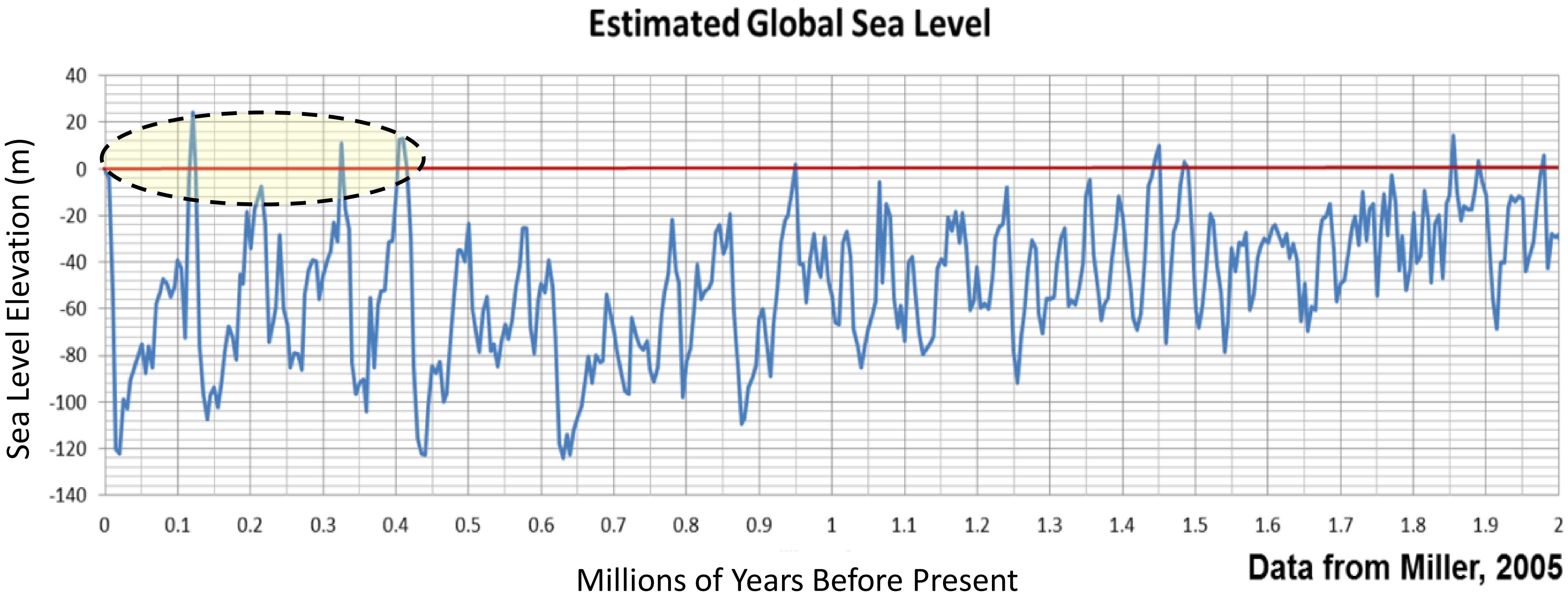
- Similar passage dimensions, & morphology suggest similar origins to underwater caves

- Provide opportunity to collect data without complex logistics or time constraints

- Sea level has only been higher than today at brief times in the geologic history of Quintana Roo (2 ma at least)

- Either caves formed very rapidly during those times…

  …or they formed deeper and have been lifted to their modern elevation



Research Framework

Assumptions of Speleogenesis:

Mixing dissolution as development process

And

Tectonic stability of the Yucatan Peninsula

- Observed today at halocline
- Occurs 1-20m below sea level
- Supported by geochemistry models
- Works rapidly in ideal conditions

If True

H1: Caves formed rapidly during Pleistocene high-stands

- Cave formations would be young
- Expect more cave passage at greater depths
- Surface erosion relatively slow
- POS elevations match sea level records

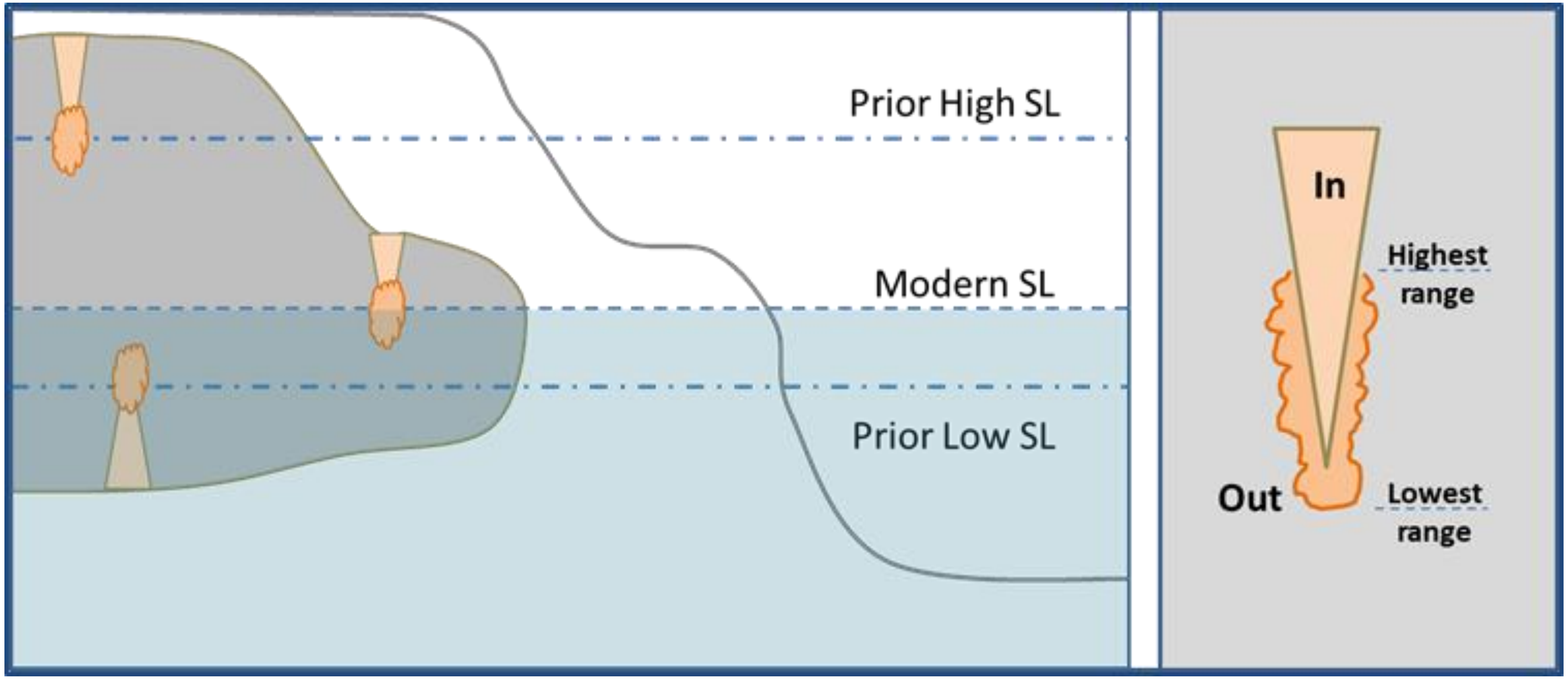
If False

H2: Caves formed at lower elevations and have been uplifted

- Cave formations could be very old
- Expect less cave development deeper in today's setting
- Surface erosion rate similar to uplift rate
- POS collected higher than sea level records indicate

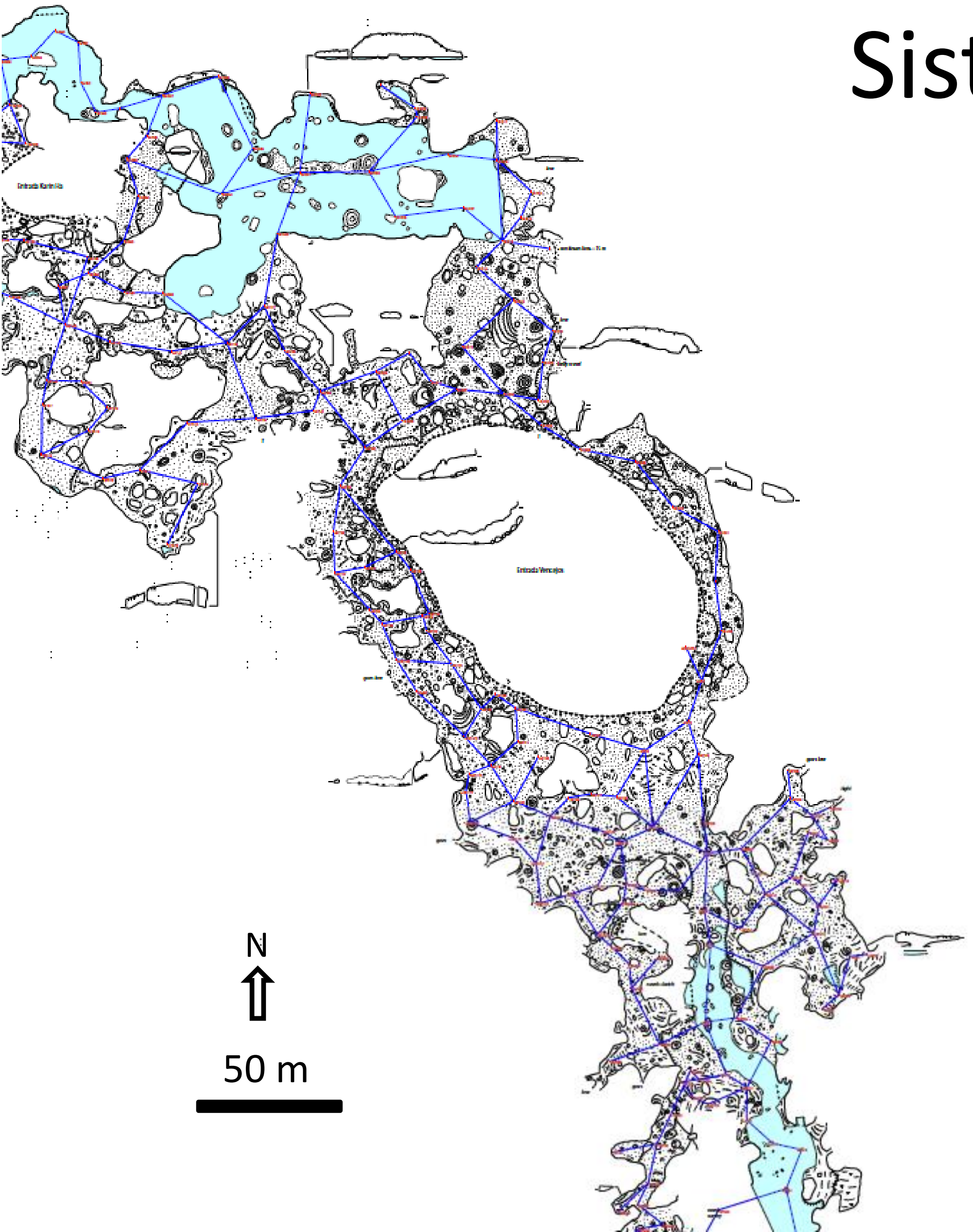
Phreatic Overgrowths on Speleothems (POS)

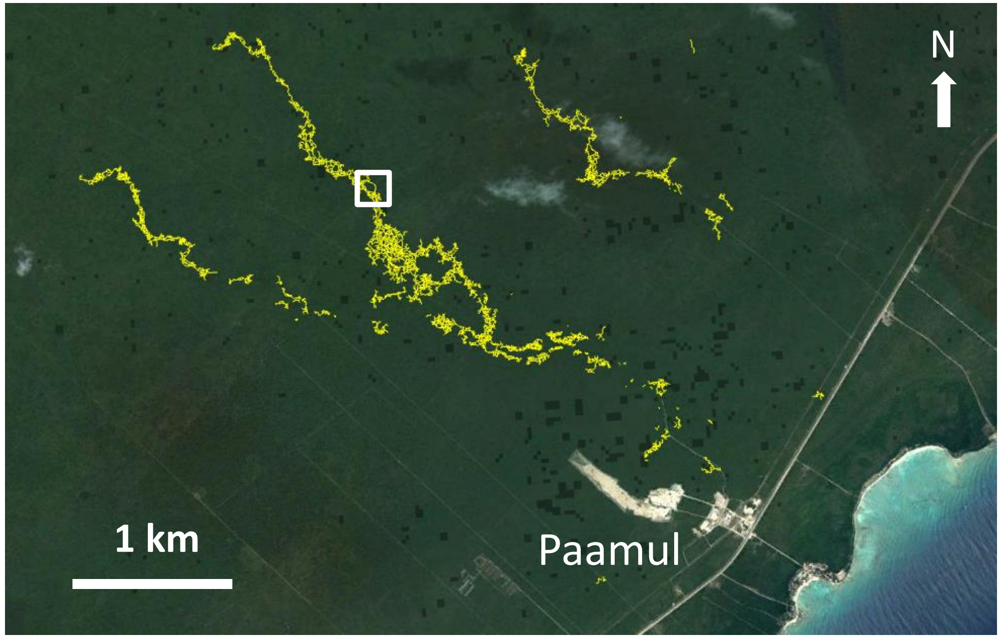
- Deposited where CO_2 outgasses at the water table
- Provides sea level proxy in low gradient systems
- Exterior crusts can be dated by U-Th methods (500 ka)
- Interior stalactites provide minimum age of cave passage



Sistema Jaguar

- Representative cave of the area
- Allows observations of the aquifer from 7 km inland to coastline
- Elevations 5-20m above sea level

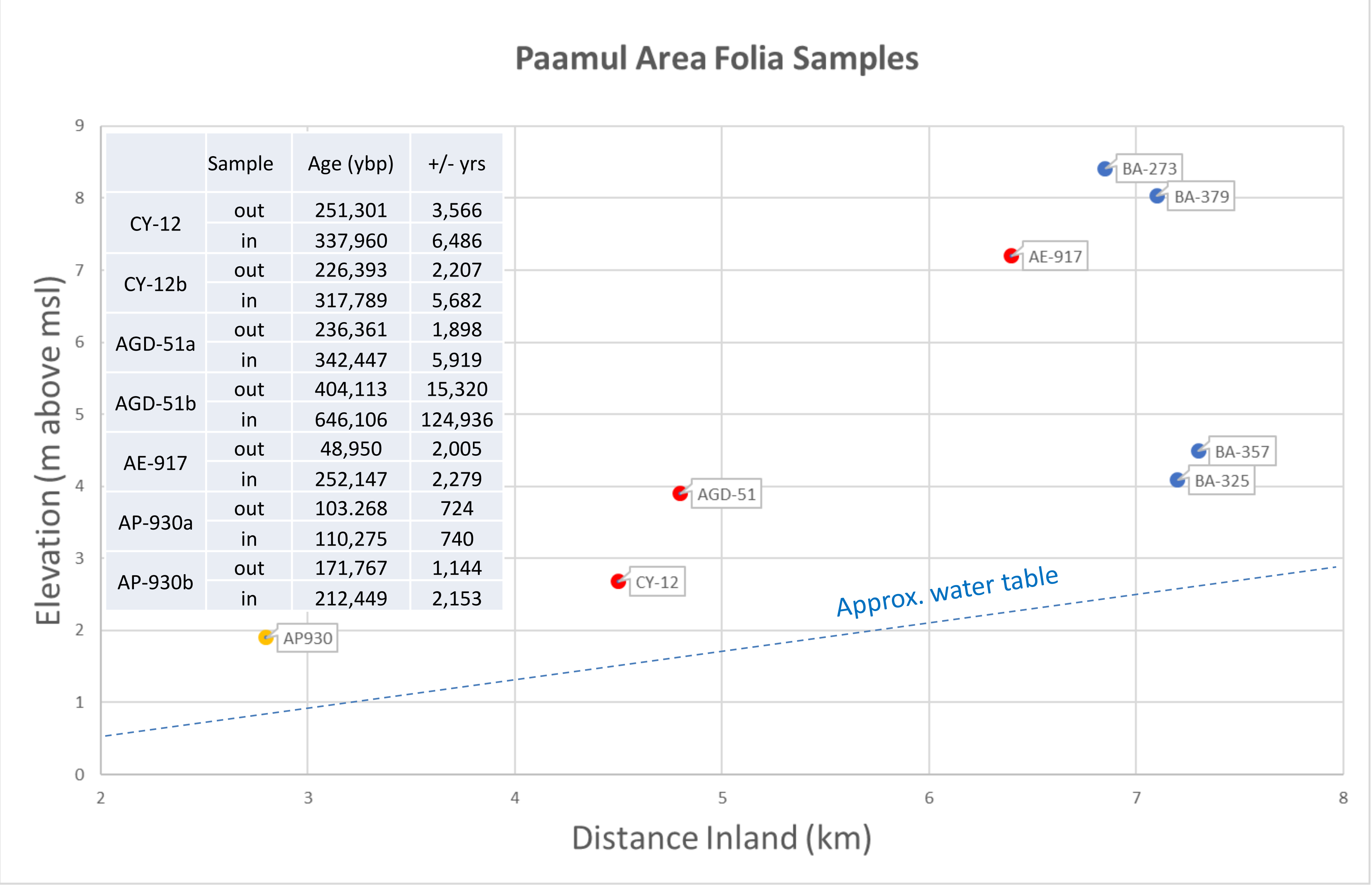




Sample locations of POS and their Interior Stalactites

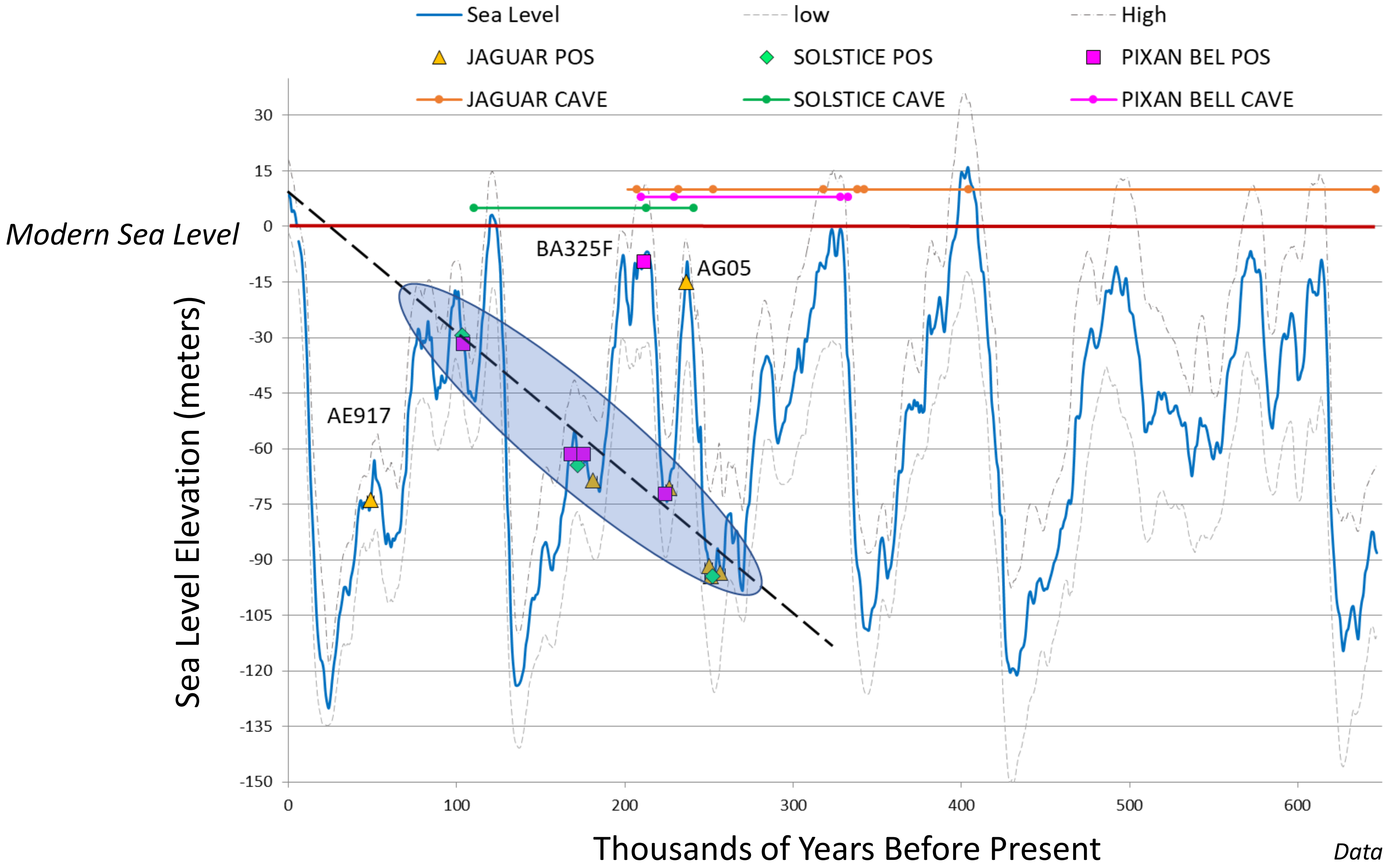
Paamul, Mexico

Sample Locations and Elevations relative to the Water Table



	Sample	Age (ybp)	+/- yrs
CY-12	out	251,301	3,566
	in	337,960	6,486
CY-12b	out	226,393	2,207
	in	317,789	5,682
AGD-51a	out	236,361	1,898
	in	342,447	5,919
AGD-51b	out	404,113	15,320
	in	646,106	124,936
AE-917	out	48,950	2,005
	in	252,147	2,279
AP-930a	out	103.268	724
	in	110,275	740
AP-930b	out	171,767	1,144
	in	212,449	2,153

Sample Ages and Elevations above MSL



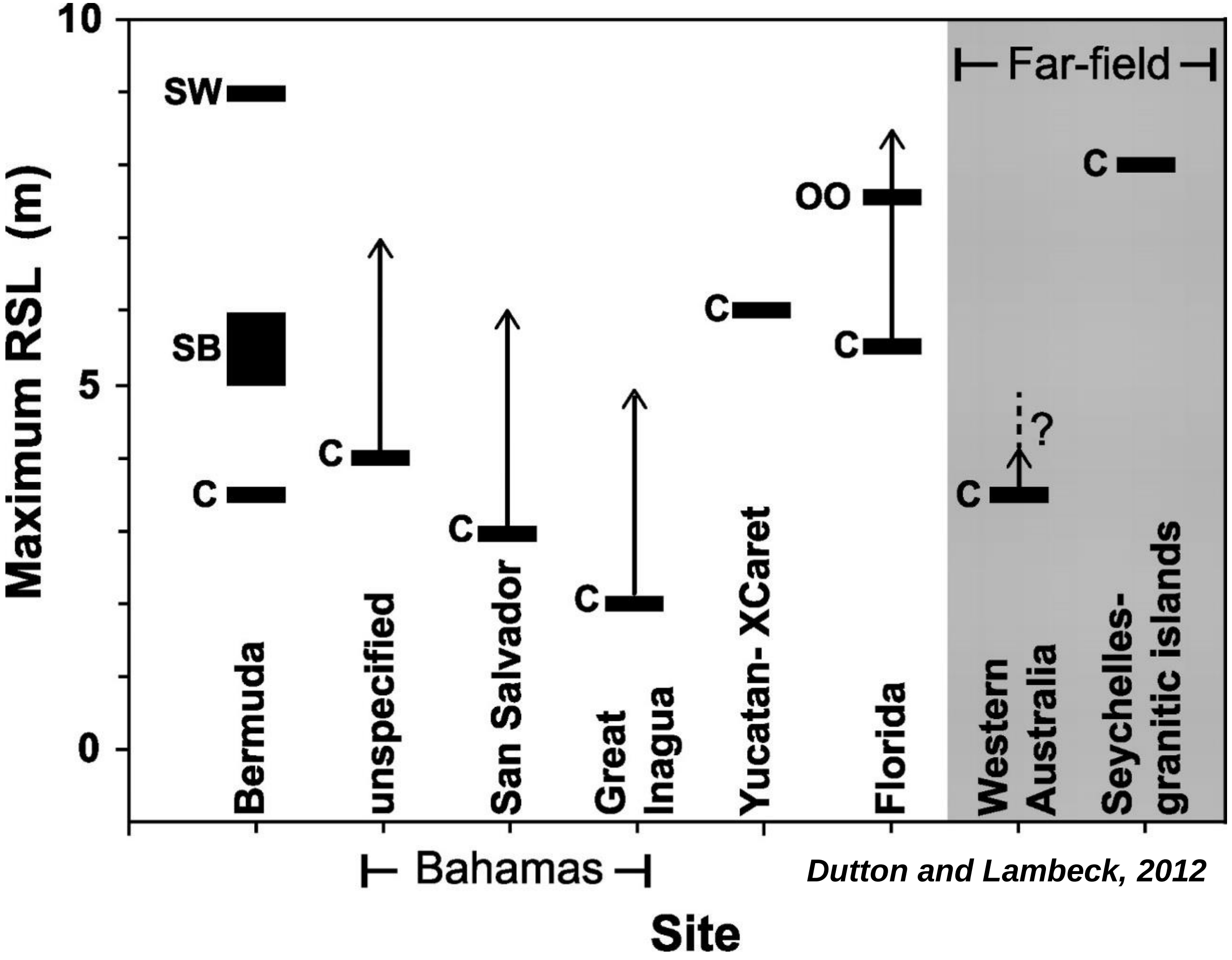
Data from Spratt et al., 2016

Tropical Karst Denudation Rates

Location	Max SL Rate (mm/ka)	Method	Source
Kikai jima, Japan	205	Pedestal	Matsukura, 2007
Aldabra atoll, Indian Ocean	260	Pedestal	Trudgill, 1976
	200	Laboratory testing	Ford et al, 1988
	175	Modeling estimate	Sheen, 2000
Bikini atoll, Marshall Islands	300	Micro Erosion Meter	Revelle and Emery, 1957
Victoria, Australia	300	Micro Erosion Meter	Gill and Lang, 1983
Grand Cayman Isl., Bahamas	177	Micro Erosion Meter	Spencer, 1985

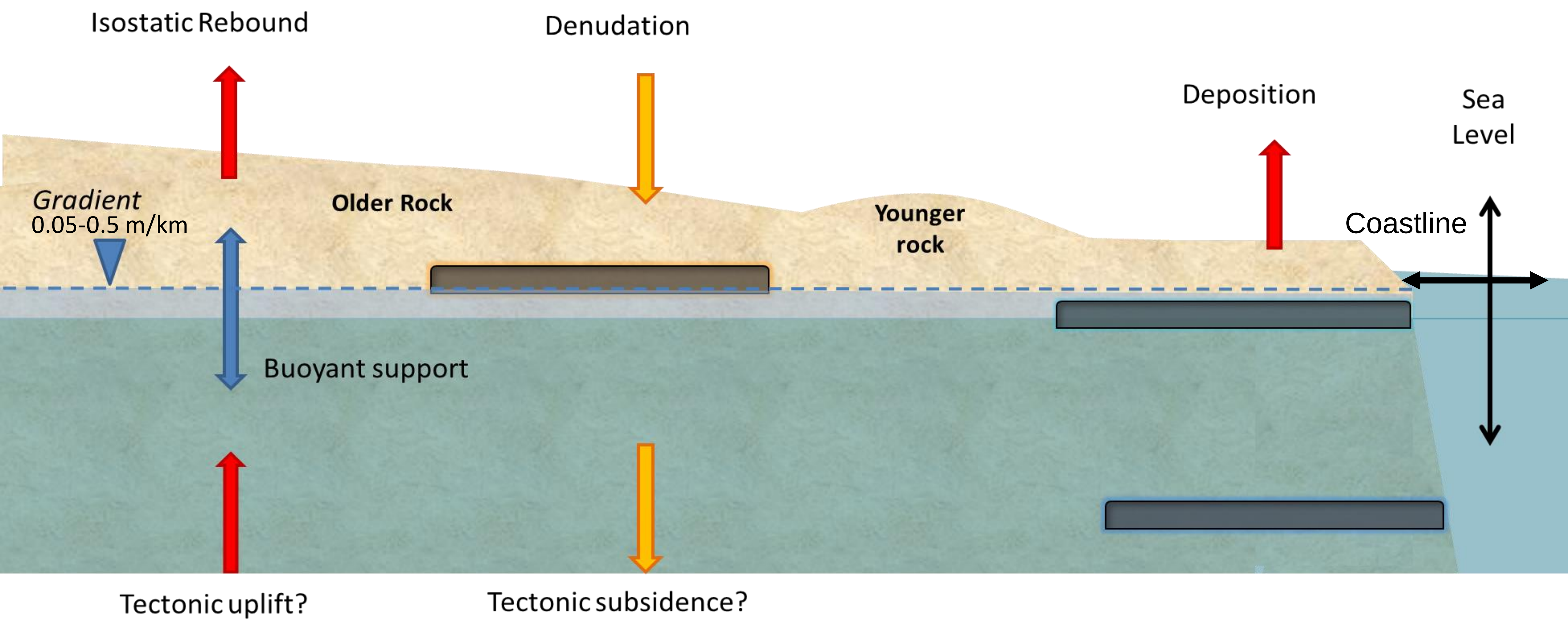
- Faster at low temperature
- Increases with rainfall
- Accelerated by pCO_2
- Humid tropics ~200 mm/ky

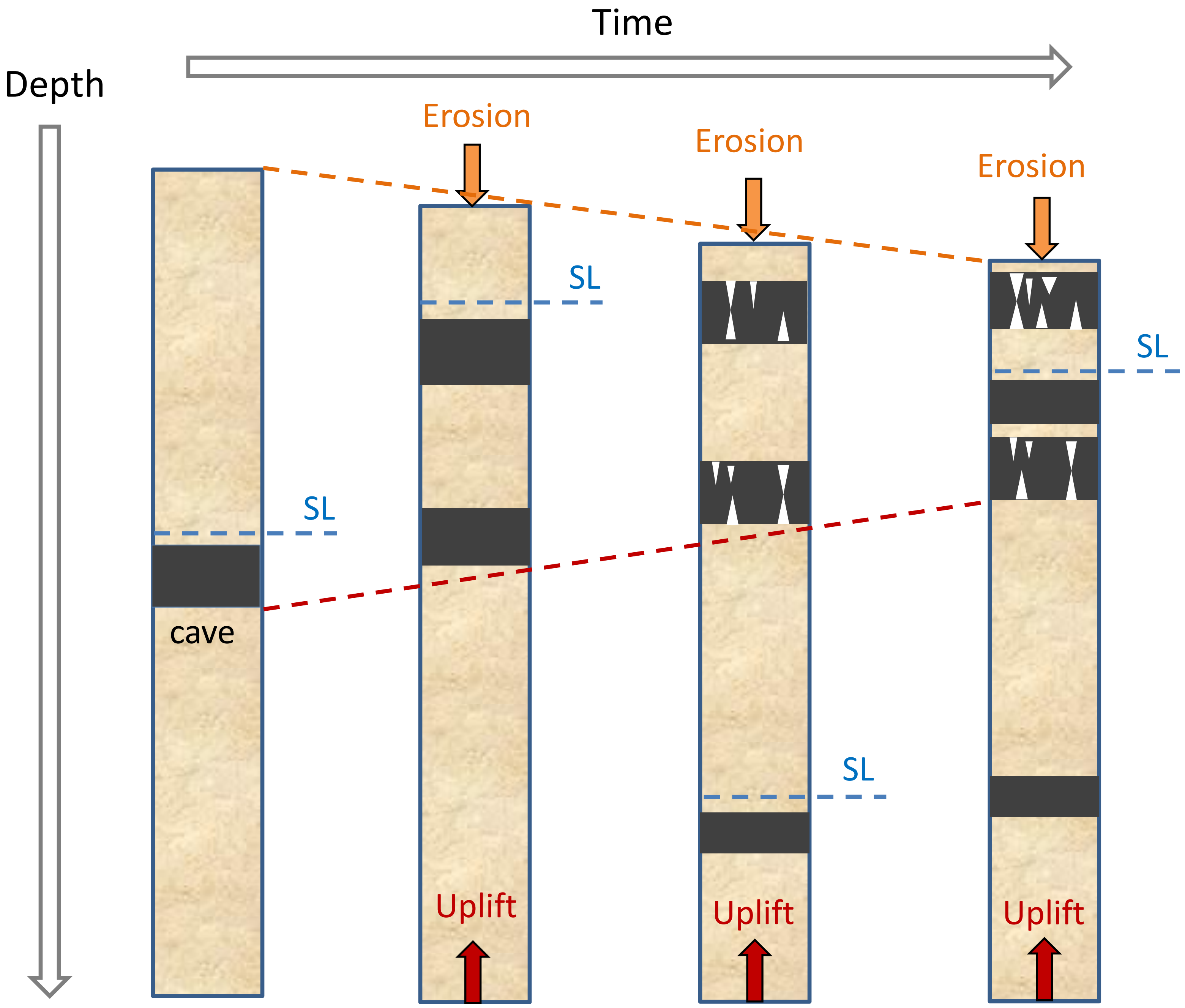
Pleistocene Coral



Dutton and Lambeck, 2012

- Minimum values with range of depth for coral growth
- Denudation not considered in modern coral elevation


Isostatic Rebound
Denudation
Deposition
Sea
Level
Gradient
0.05-0.5 m/km
Older Rock
Younger
rock
Coastline
Buoyant support
Tectonic uplift?
Tectonic subsidence?


Time
Depth
Erosion
Erosion
Erosion
SL
SL
SL
SL
cave
Uplift
Uplift
Uplift

Conclusions

- Caves cannot have formed during the Pleistocene high-stands based on a speleothem age of 600 ka indicating existing passage

- Assuming consistent low gradients, elevation differences in POS indicate uplift of the Yucatan Peninsula ~350 mm/ka

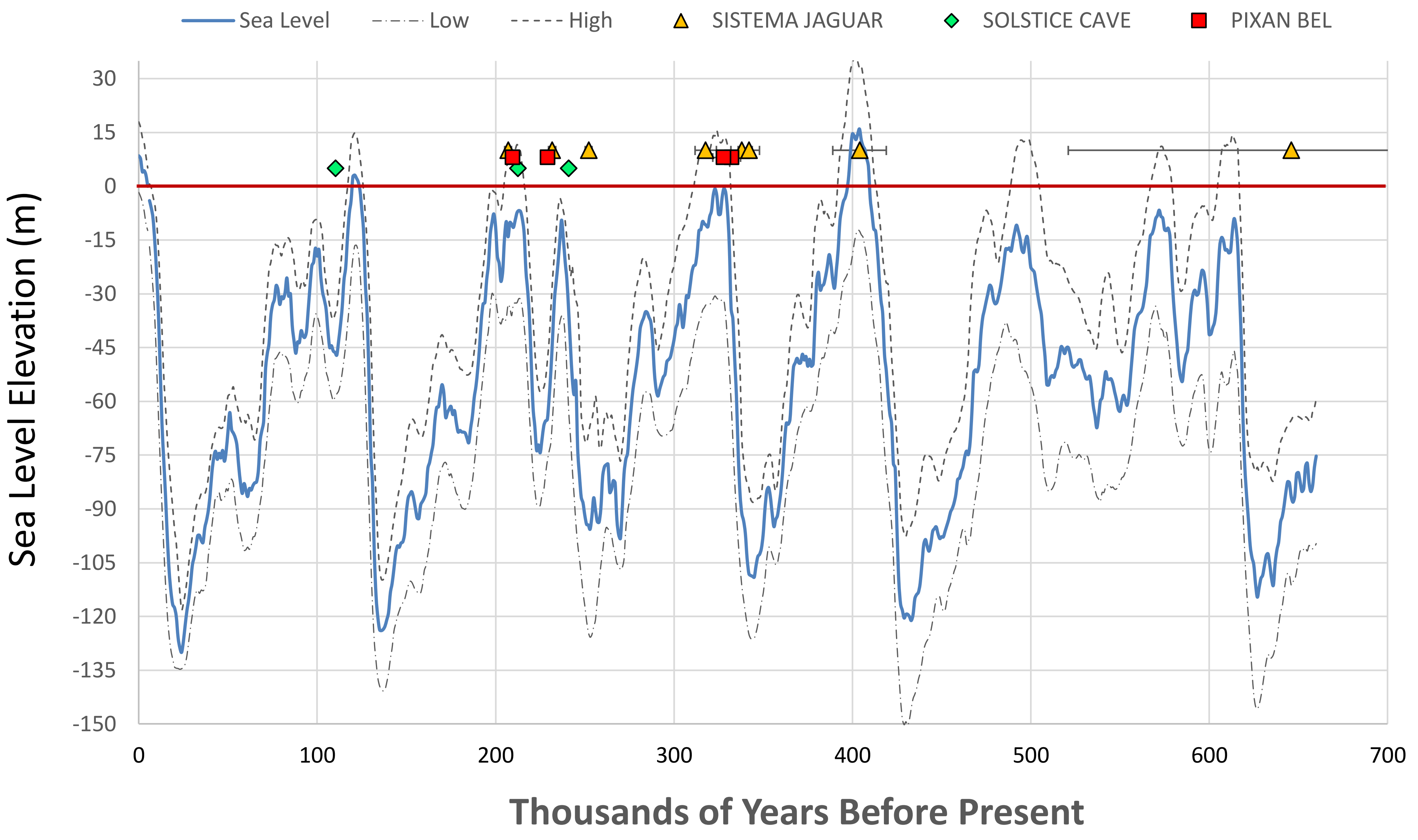
- Denudation 0f 200 mm/ka would result in apparent uplift of 150 mm/ka

Acknowledgements

- Geological Society of America
- National Speleological Society
- Lions Club International, San Marcos Chapter
- UT Grotto and Paamul Grotto
- Lorena Martinez, Peter Sprouse, Christine Lowe, Barbara Luke, Nick Banks, Andy Edwards, Cait McCann, Jessica Gordon, Edgar Iglesias, and many others for their assistance and company in the field.

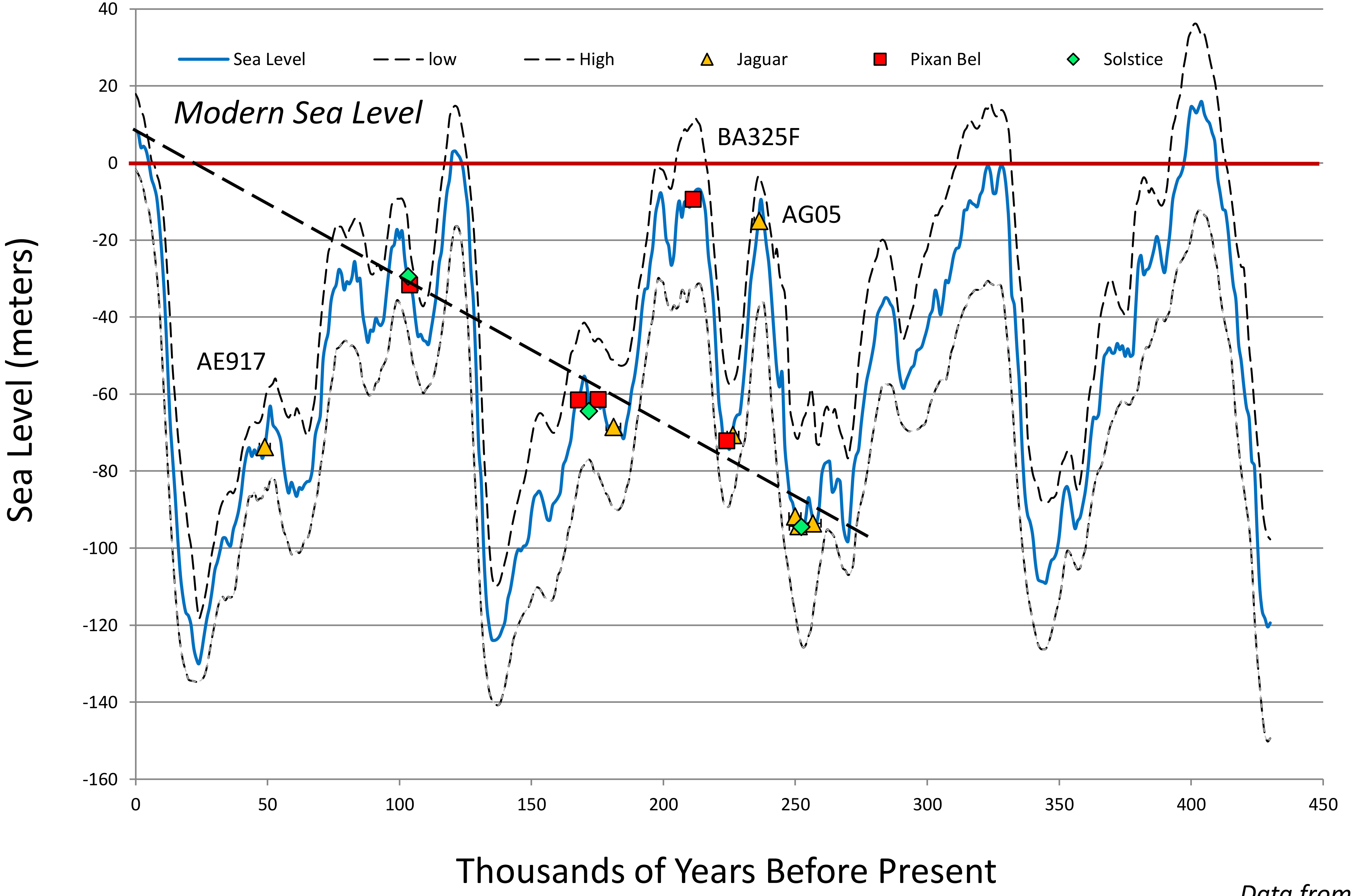
Questions?

U-Th Ages of Interior Stalactites on North Atlantic Sea Level Curves



Data from Spratt et al., 2016

POS U-Th ages on North Atlantic Sea level curves



Data from Spratt et al., 2016