Lophelia II: Growth Rate and Age Distribution of Deep-Sea Black Corals in the Gulf of Mexico

Nancy G. Prouty
USGS Pacific Coastal and Marine Science Center

E. Brendan Roark
Texas A&M

Noreen Buster & Chuck Holmes
USGS–St. Petersburg

Alan Koenig
USGS–Denver

Steve W. Ross
University of North Carolina–Wilmington

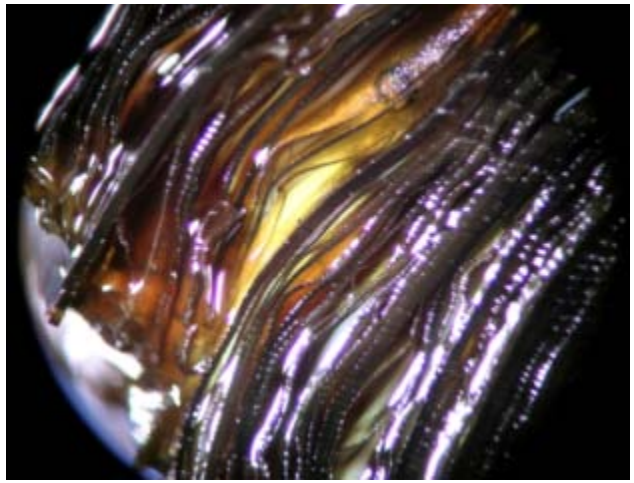
Introduction: Black Corals

Colonial cnidarians
Order Antipatharia

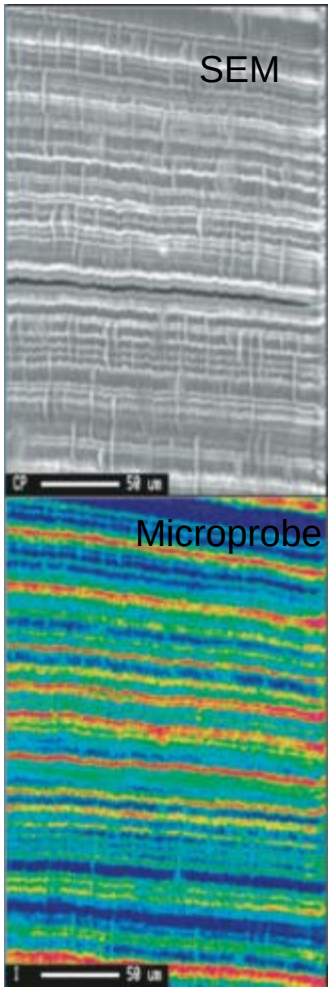
Greater than 30 m water
Tropical western Atlantic & SW Pacific

20 species in GOM
4 species at Viosca Knoll; one of largest megafauna taxa at VK *(Sulak et al. 2008)*

Introduction: Skeletal Growth



skeletal microlayers.



SEM and microprobe images

<u>Chitin fibrils mixed with proteins</u>

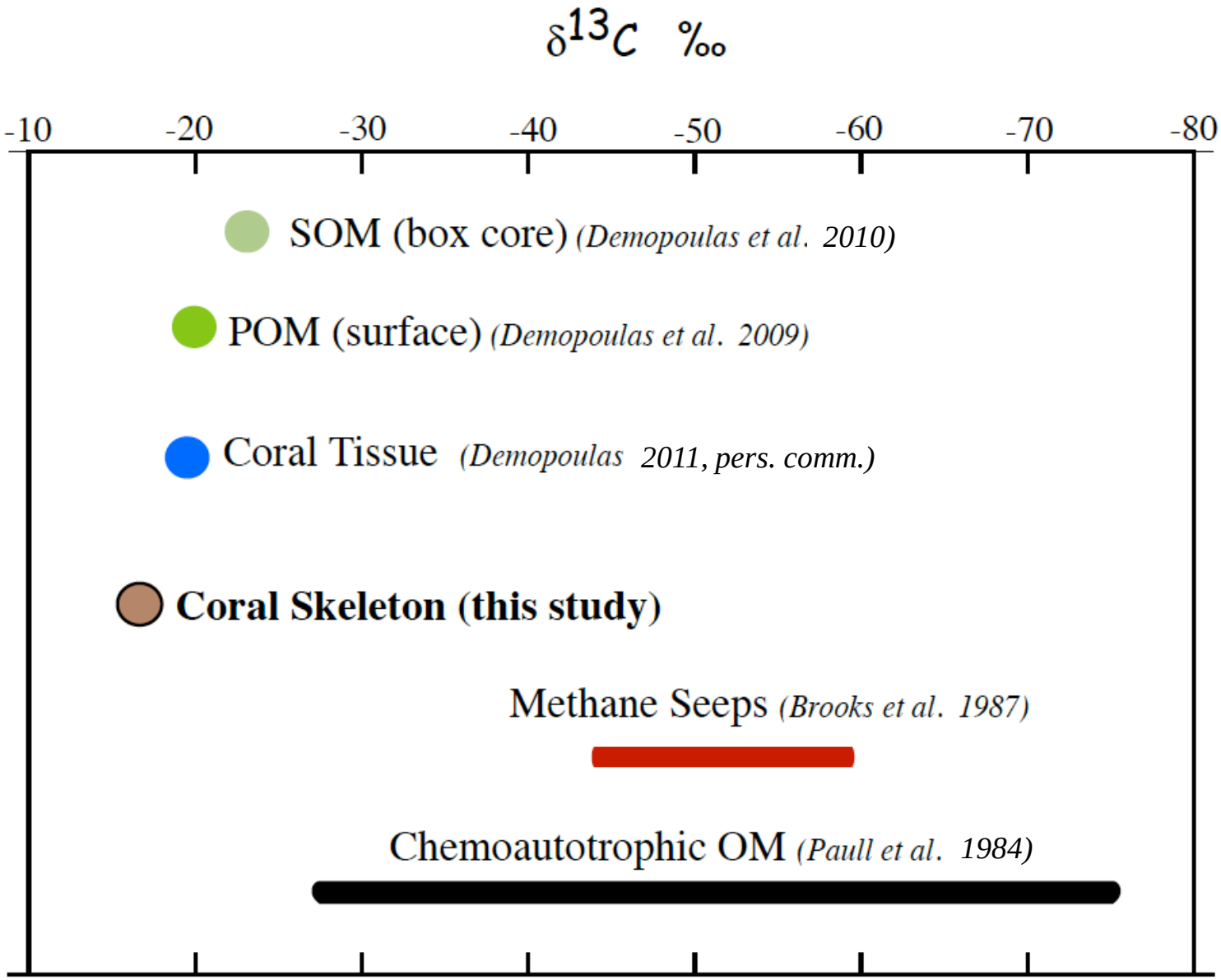
10–15% chitin

50% protein (e.g., histidine)

2-3% halogens (e.g., iodine)

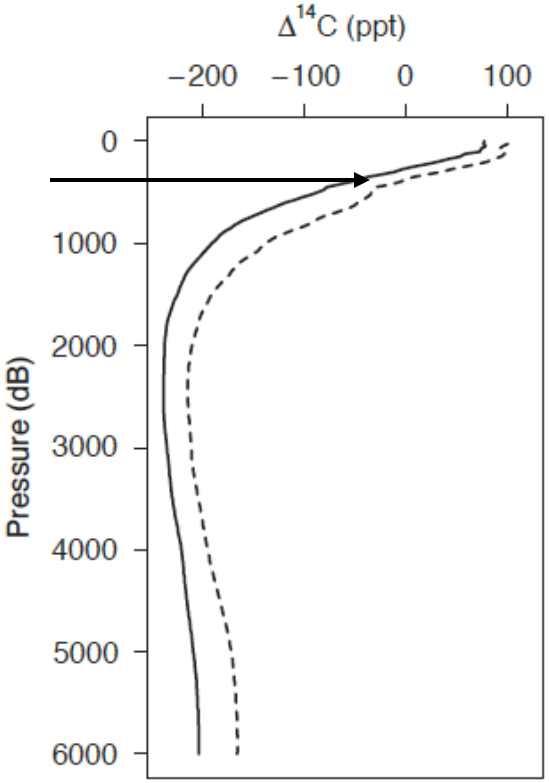
(Goldberg et al. 1994)

Introduction: Food Source



Introduction: Food Source

Sinking Particulate Organic Matter
~zooplankton, phytoplankton



Key 2001

<u>Organic Carbon Sources</u>

DOC -210 ‰
SOC -170 ‰ } ~1,000 m

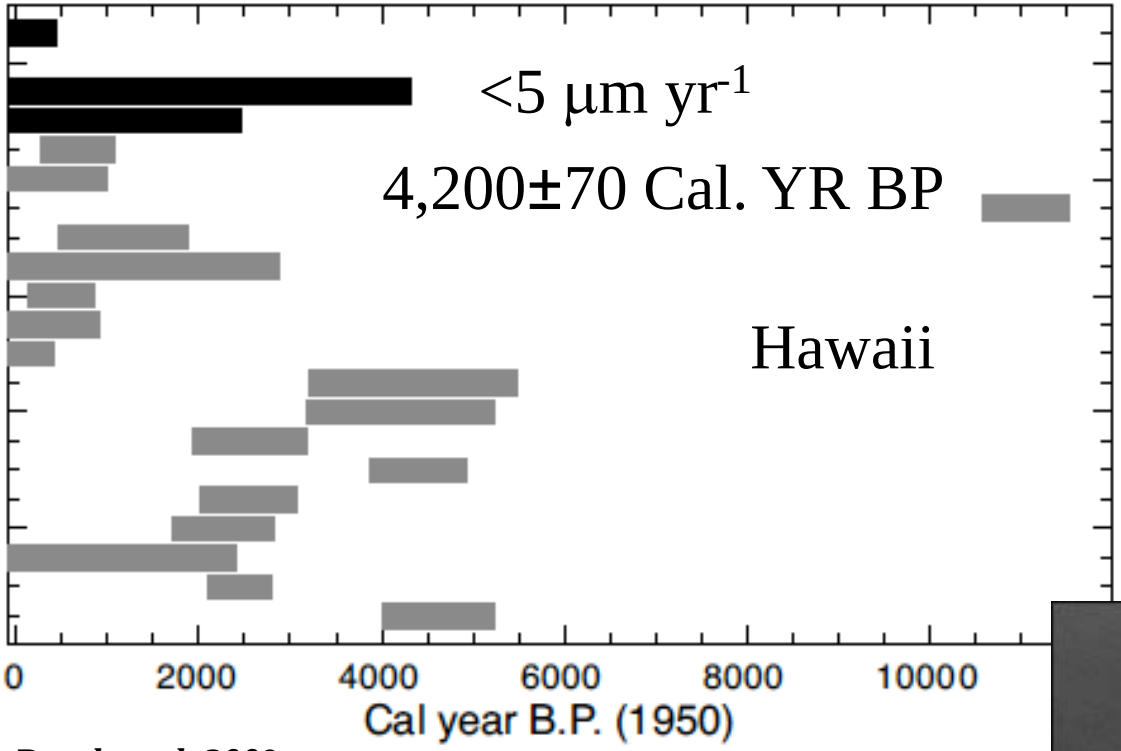
POC +128 ‰ *(Druffel et al. 1995)*

<u>Gulf of Mexico</u>

Coral $\Delta^{14}C$ +47 to +72 ‰

Collected at ~ 300 m

Introduction: Growth Rate and Ages

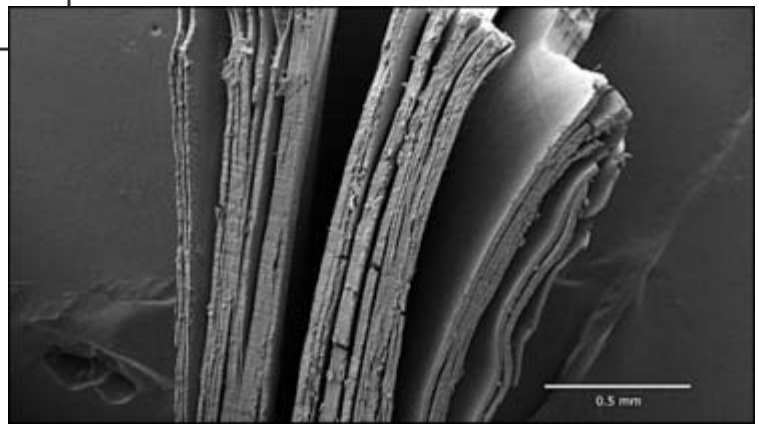


Roark et al. 2009

<u>GOM</u>

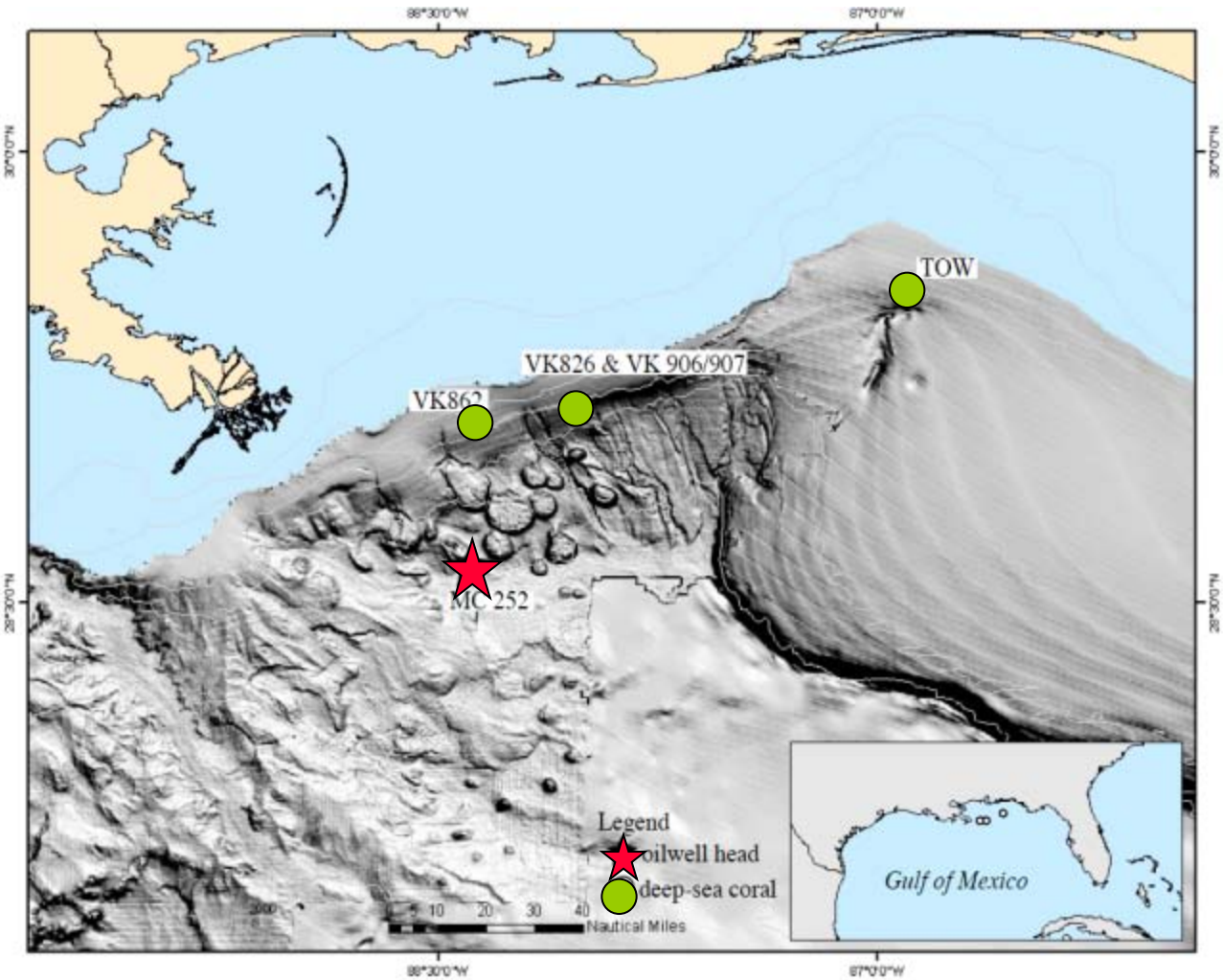
14.5 μm yr^{-1}

386 years



Williams et al. 2006

Methods: Study Site



2003–2009 (*CSA 2007; Sulak et al. 2008*)

TOW: De Soto Canyon

VK: Viosca Knoll

-fine-grained aggregates

-riverine origin

-high organic carbon content

(Davies et al. 2010)

Johnson-Sea-Link

Methods: Sampling

Cross-sectional disc

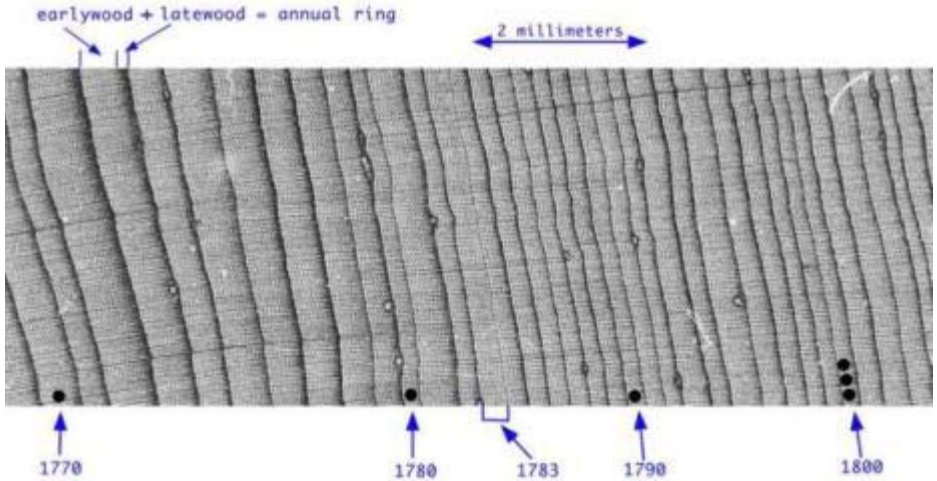
after soaking in KOH

Delaminated layers

Methods: SEM

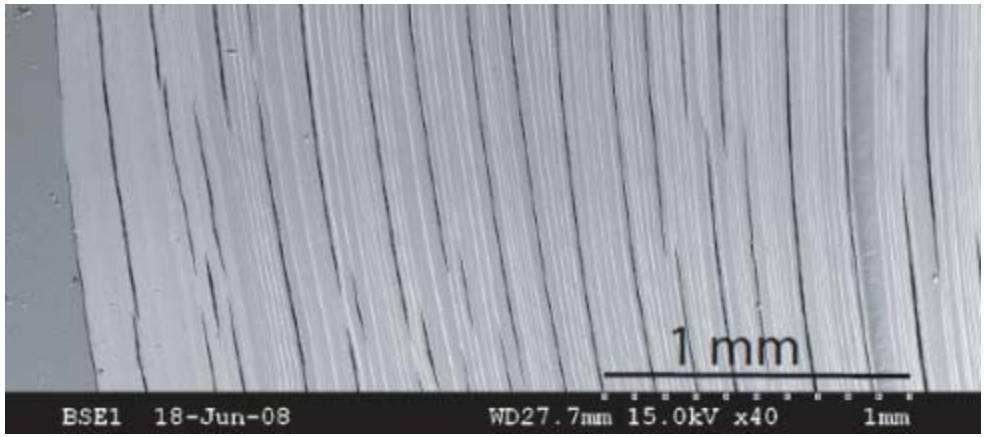
Coral thin section

Tree Ring



The Earth Institute at Columbia University

Coral SEM

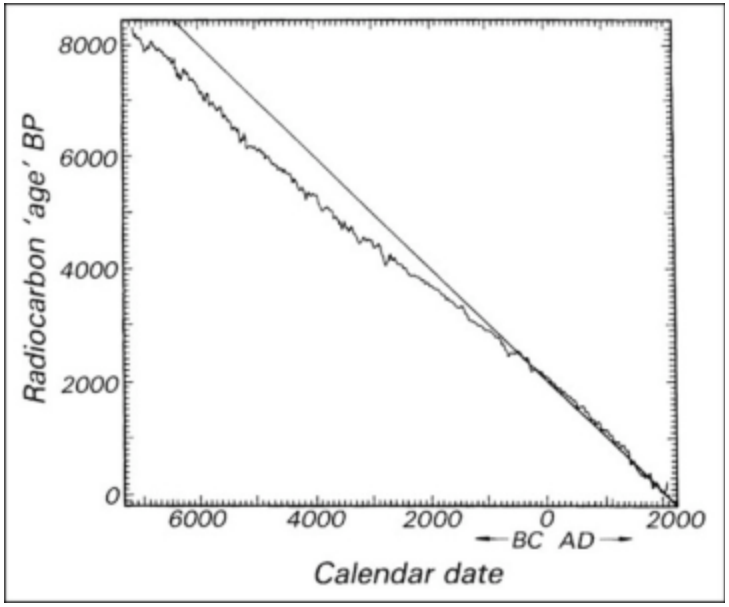


Methods: ^{14}C chronology

- ^{12}C, ^{13}C (stable)
- ^{14}C (radioactive) $t_{1/2}$ =5568±30 yrs

$$t(BP) = \frac{1}{\lambda} \ln \frac{N}{N_0}$$

- Conventional Radiocarbon Age Calibrated/ Cal. Yr



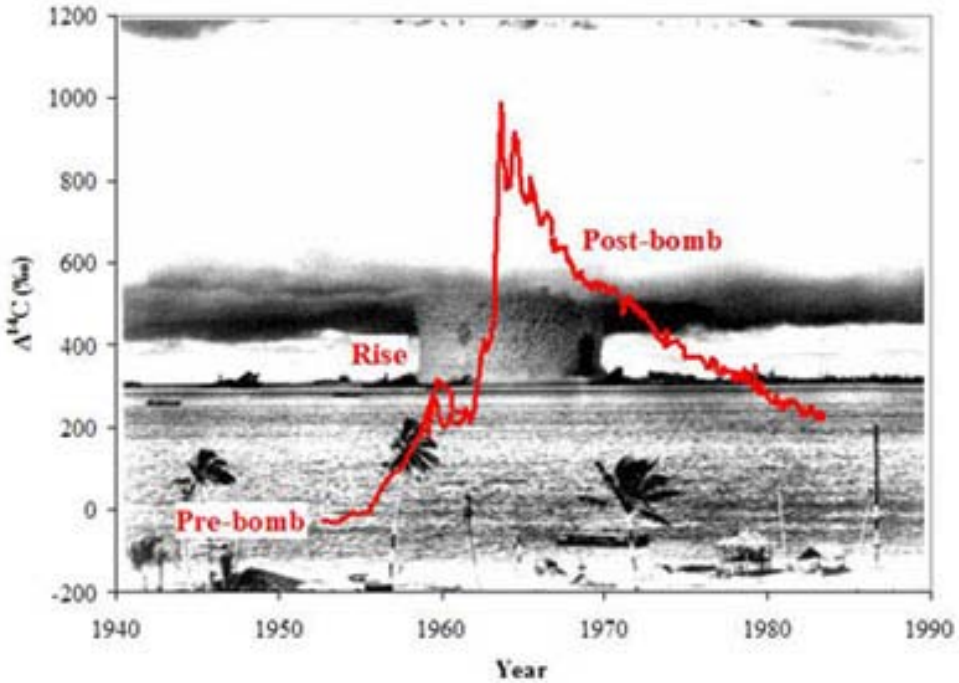
- Reservoir corrected

Reservoir age=240±10 ^{14}C yrs

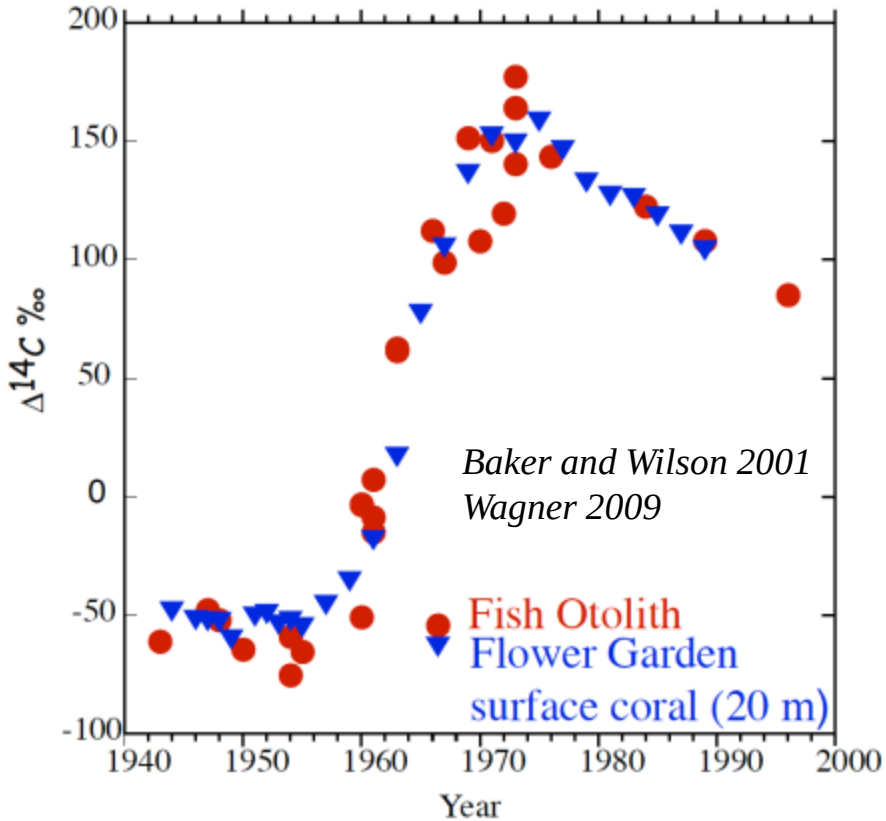
(ΔR=-30 ±24 ^{14}C yrs)

Wagner et al. 2009

Methods: “Bomb Curve”

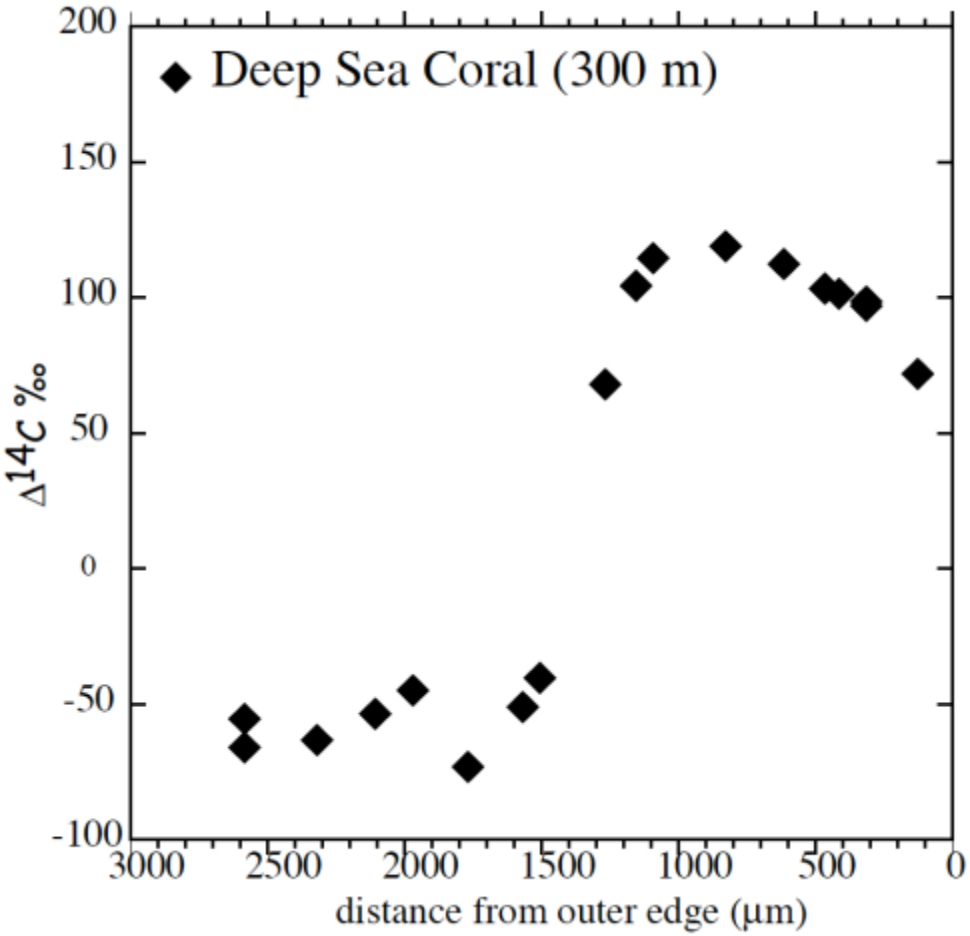


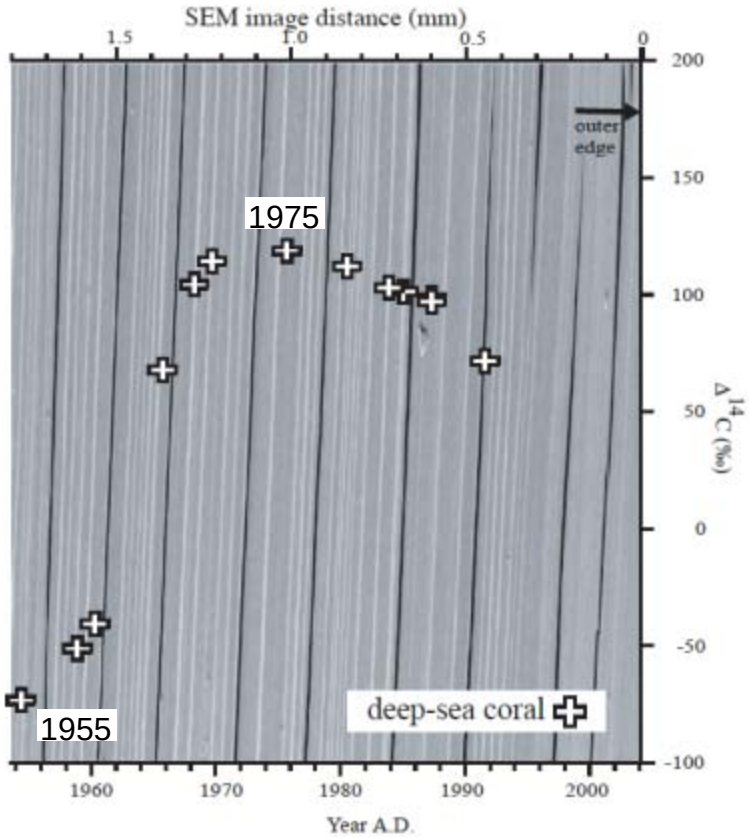
Gulf of Mexico
“Surface water” $\Delta^{14}C$



Results: “Bomb Curve”

Viosca Knoll





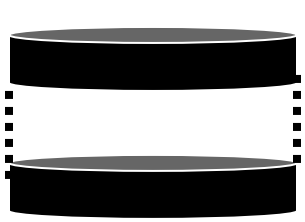
Prouty et al. 2011

Results: Radiocarbon Age

Sample	^{14}C age inner	^{14}C age outer	Outer $\Delta^{14}C$ (‰)	Inner $\Delta^{14}C$ (‰)
GOM-TOW-BC1[1]	1090 ± 35	550 ± 35	-73 ± 3.9	-133 ± 3.4
GOM-TOW-BC1[2]	1080 ± 25	550 ± 60	-73 ± 3.5	-132 ± 2.7

KOH[2,3]

Microdrill[1]



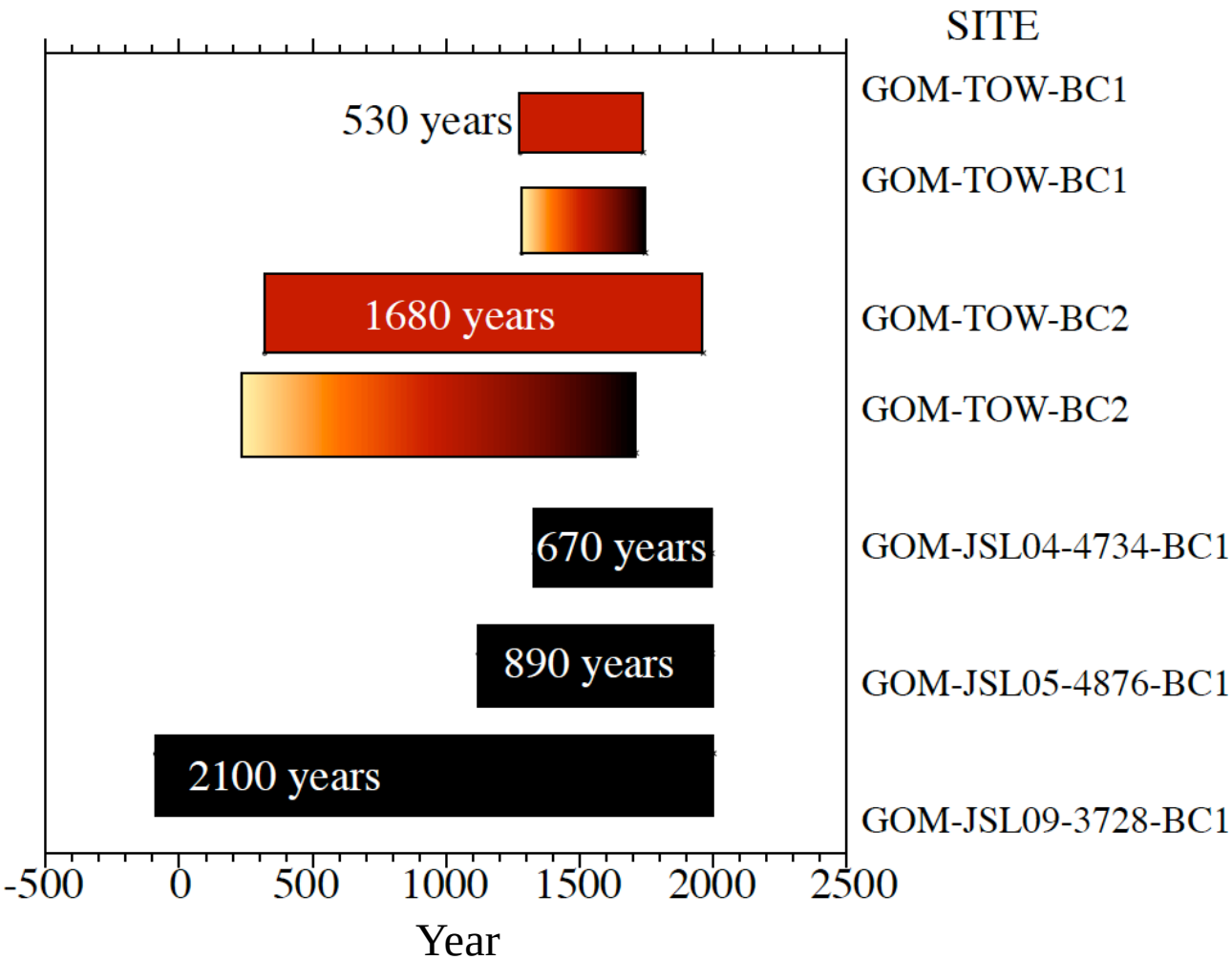
Adjacent discs

Results: Radiocarbon Age

Sample	^{14}C age inner	Cal yr BP	^{14}C age outer
GOM-TOW-BC1	1080 ± 25	670 ± 36	550 ± 60
GOM-TOW-BC2	2030 ± 15	1630 ± 30	Modern
GOM-JSL04-4734-BC1	1020 ± 30	620 ± 40	Modern
GOM-JSL05-4876-BC1	1260 ± 30	830 ± 40	Modern
GOM-JSL09-3728-BC1	2380 ± 30	2040 ± 40	Modern

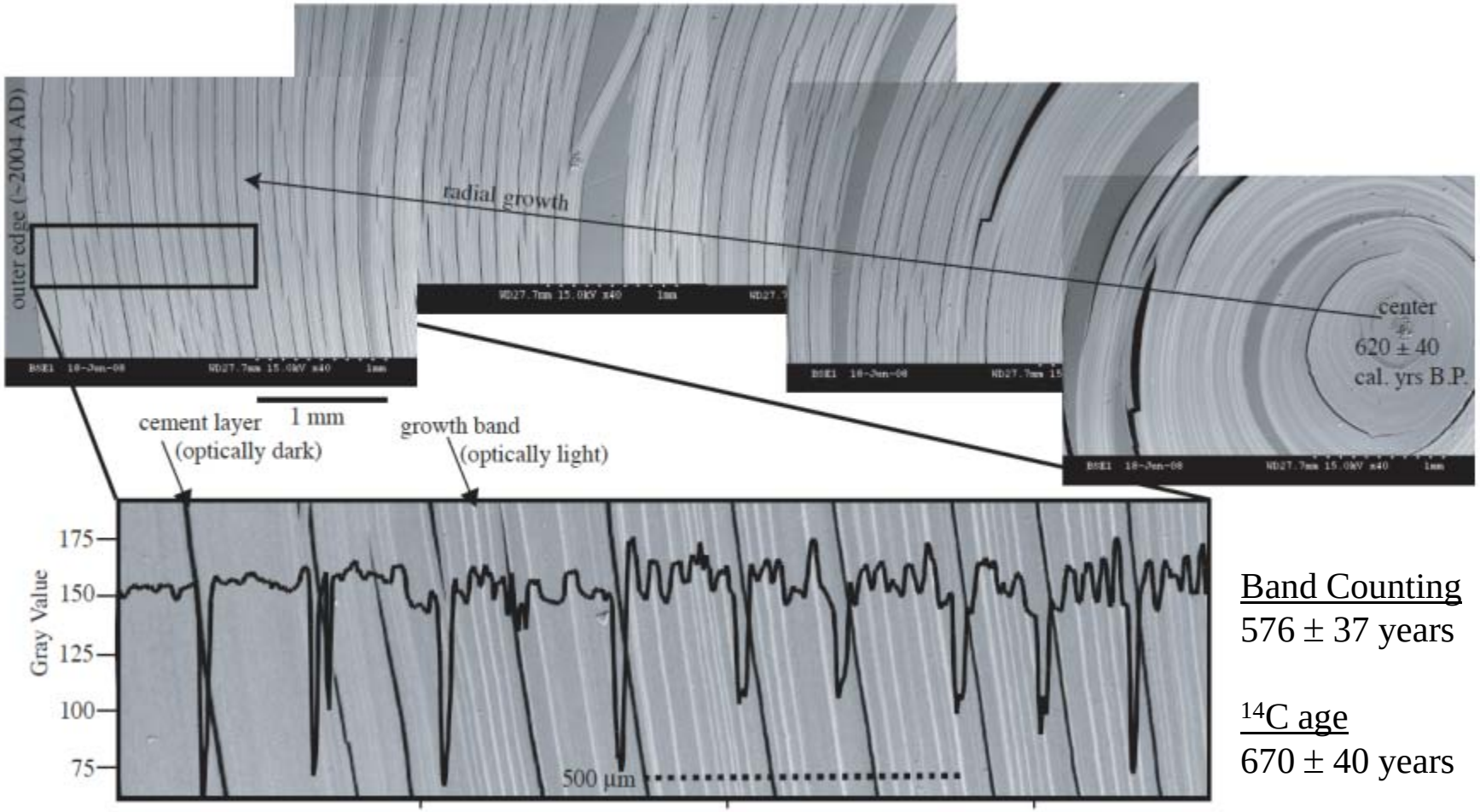
- 4 samples contain modern $\Delta^{14}C$ (1960 or younger)
- Oldest sample dated to 2040±40 Cal yr B.P. (90 B.C.)
- Youngest sampled dated to 620±40 (1330 A.D.)

Results: Life Spans



Prouty et al. 2011

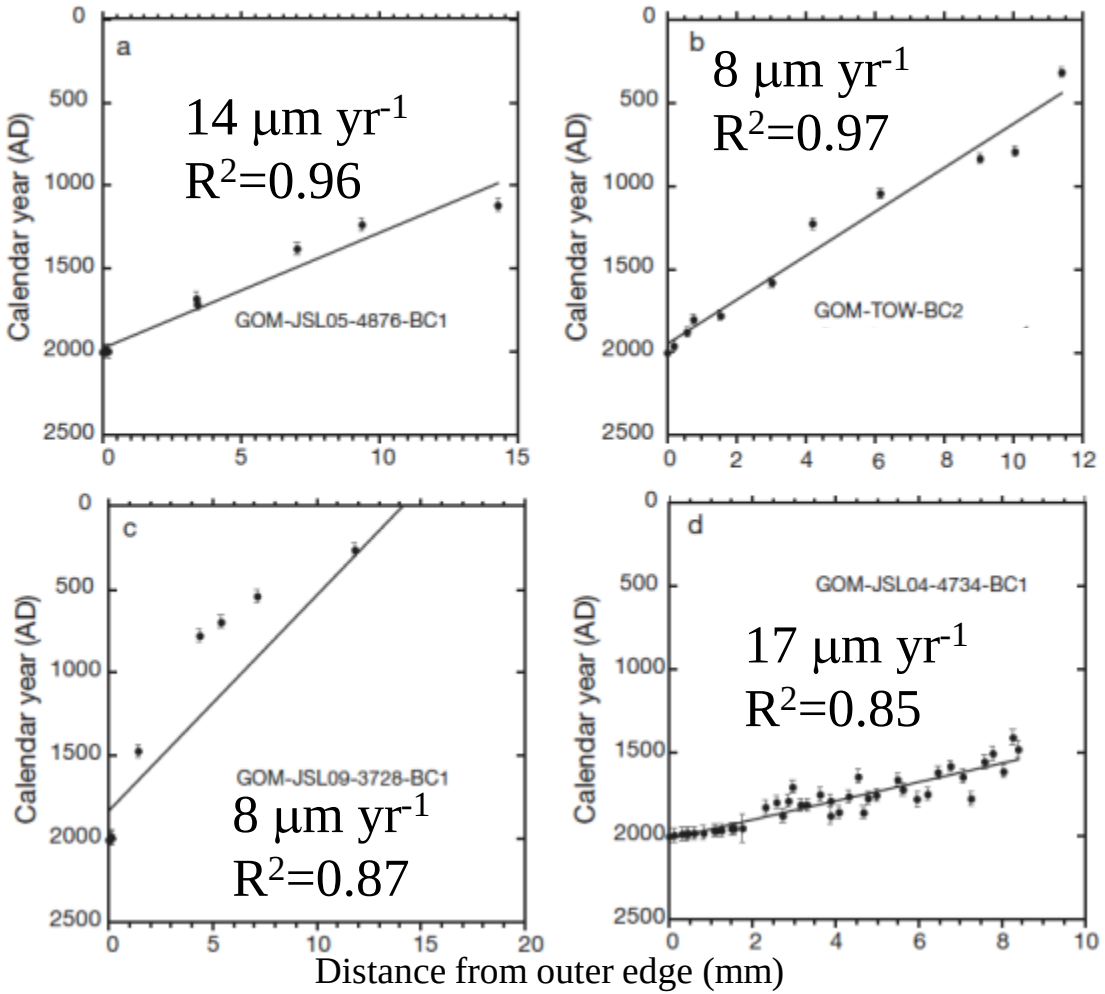
Results: SEM



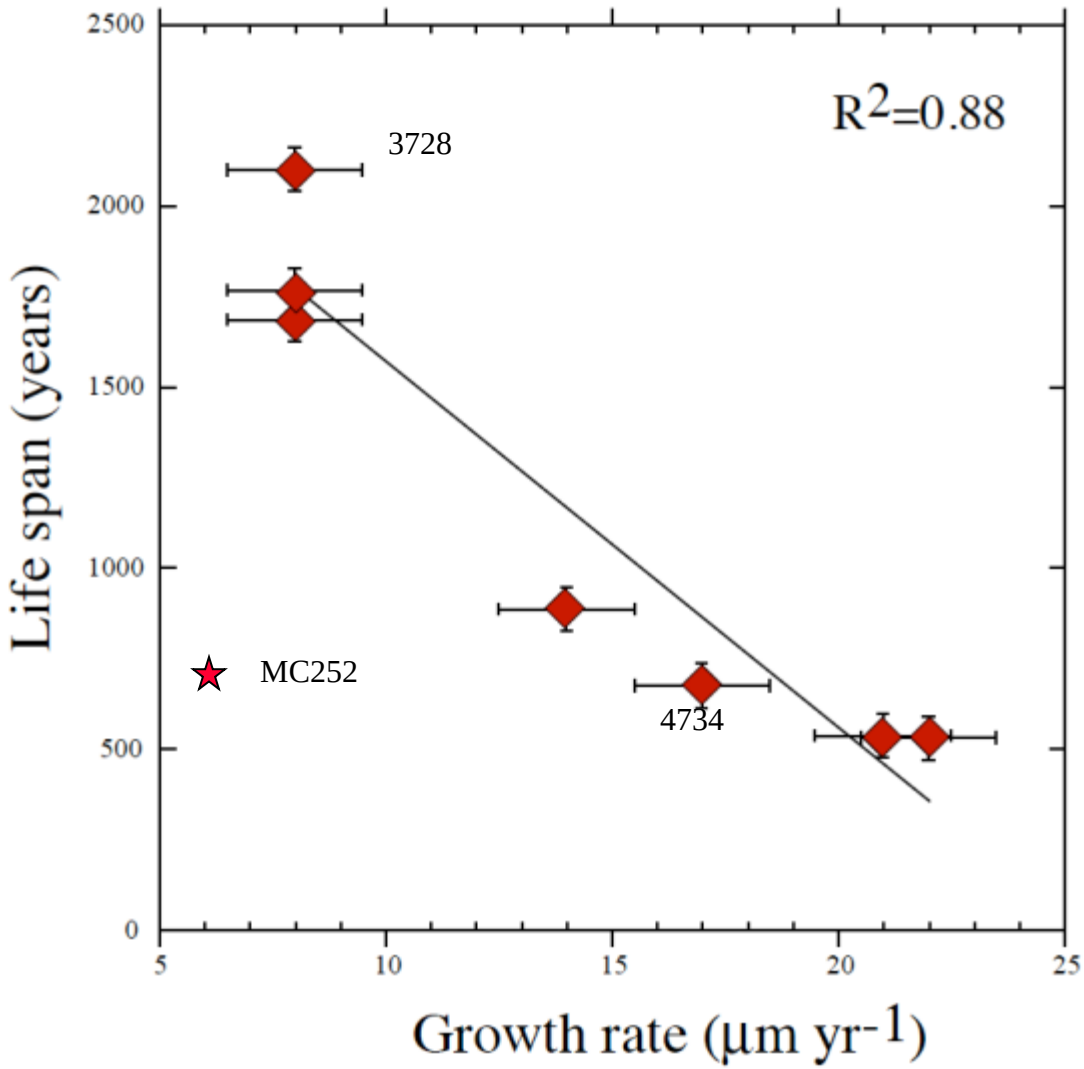
<u>Band Counting</u>
576 ± 37 years

<u>^{14}C age</u>
670 ± 40 years

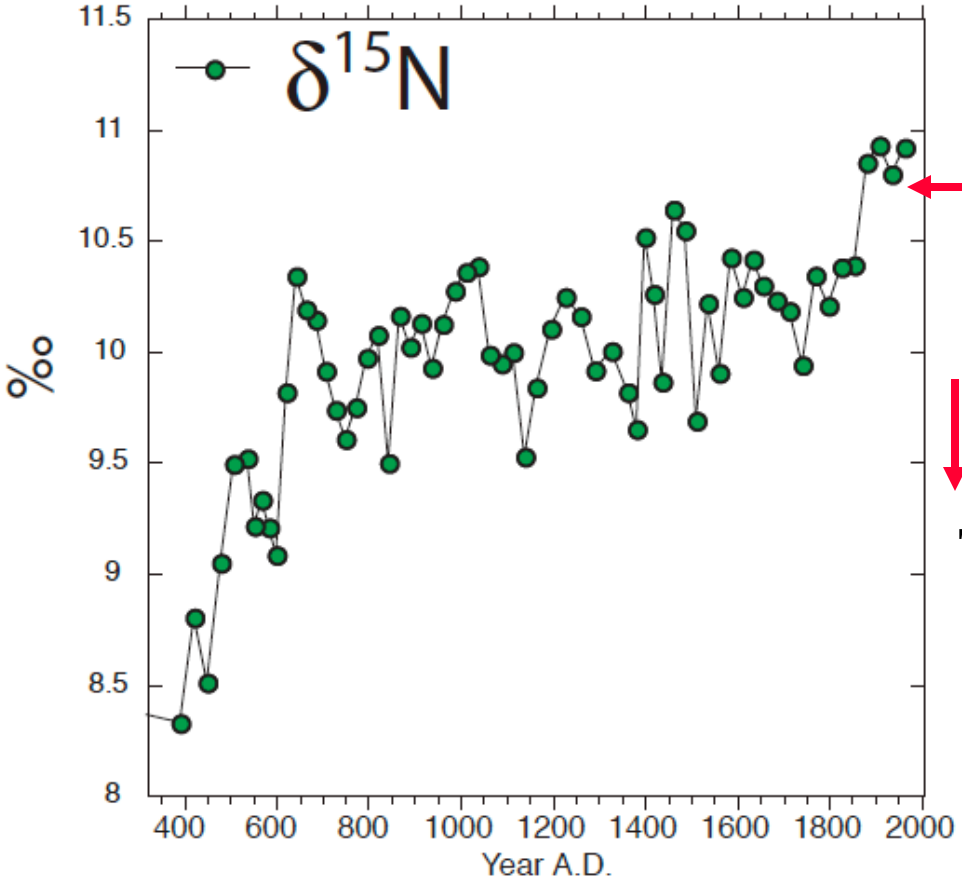
Results: Growth Rates



Results: Life Span vs. Growth Rate



Results: Stable Isotopes



$\delta^{15}N_{tissue}$
10.76 ‰

$\delta^{15}N_{POM}$
3.8 ‰

$$TP=[(\delta^{15}N_{con}-\delta^{15}N_{base})\Delta^{15}N]-TL_{base}$$

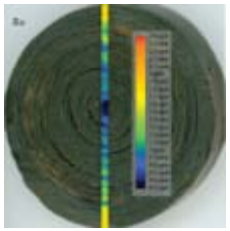
(Vander Zanden & Rasmussen 2001)

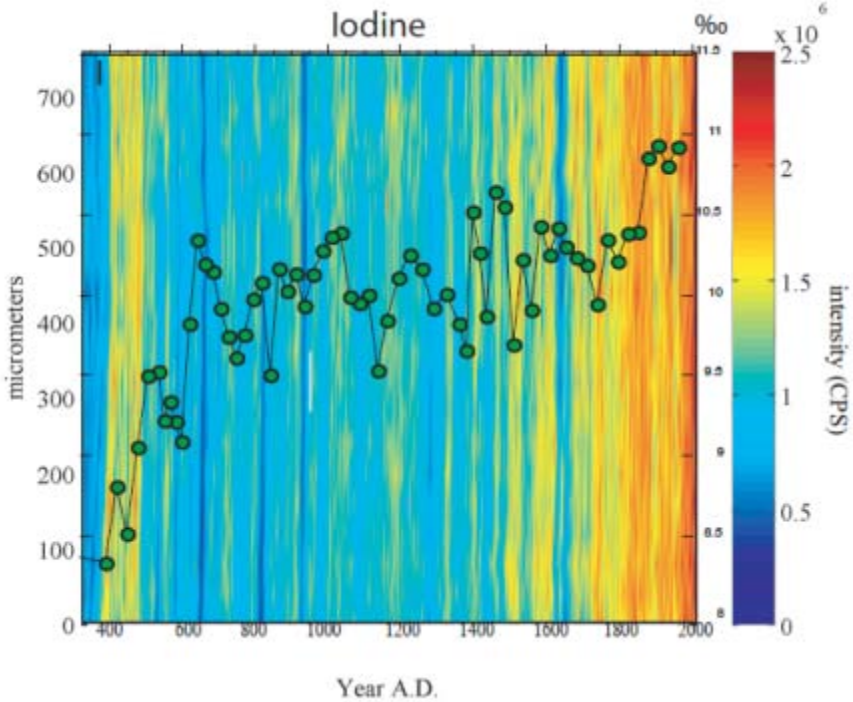
Consumer=black coral

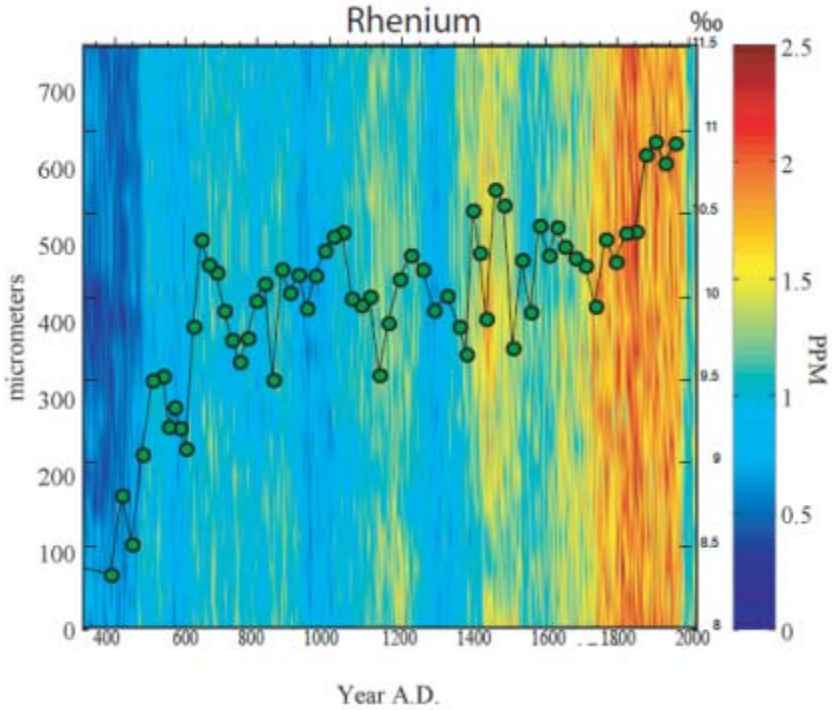
Base=copepod *(Demopoulos et al. 2010)*

TP=3.6

Results: Trace Metals



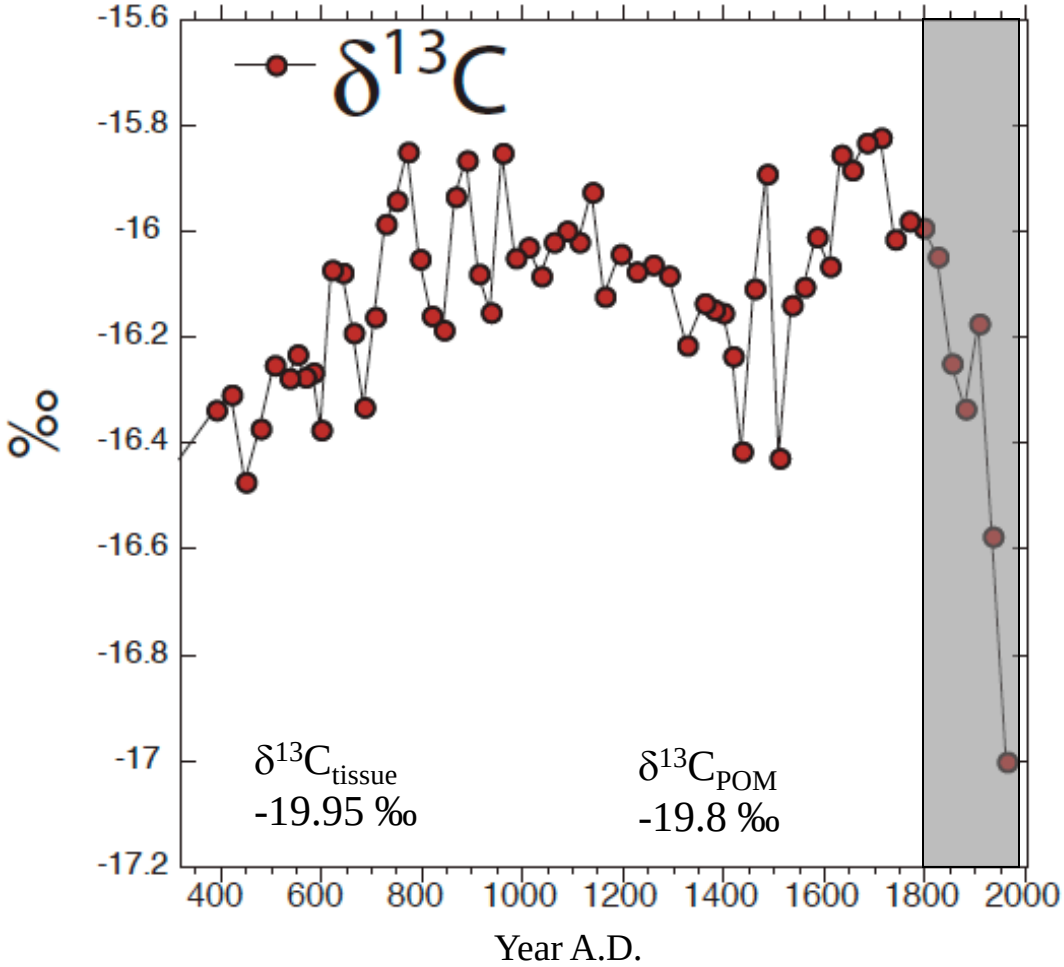




Mississippi River has [Re] 40x > global average (Rahaman and Singh 2010)

Increased [I] positive correlation with Mississippi R. flow rate (Oktay et al. 2001)

Results: Stable Isotopes



(Demopoulos et al. 2010)

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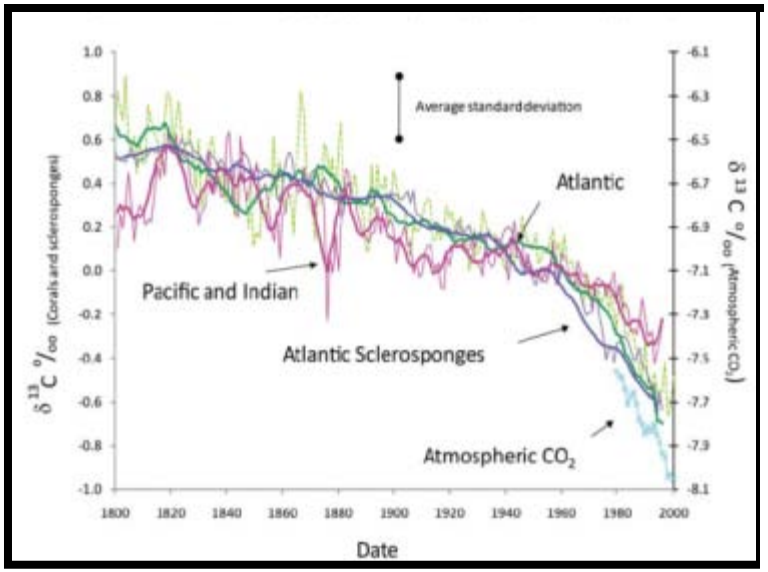


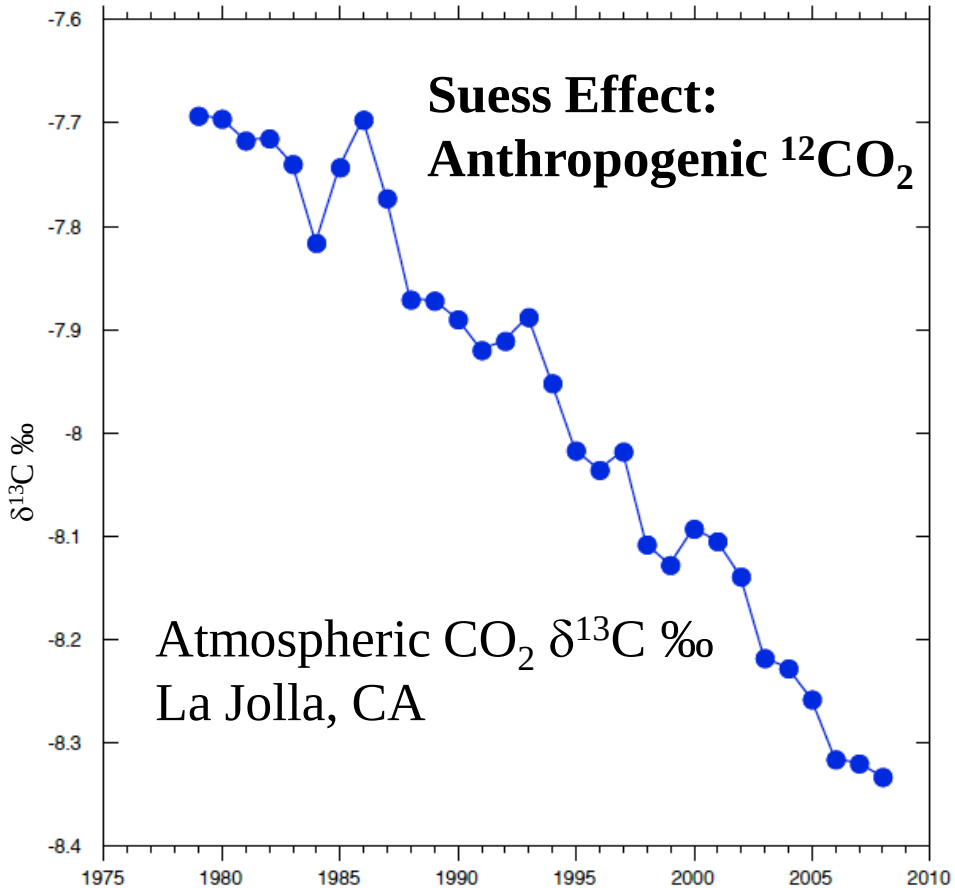
Swart et al. 2010

<u>DSC Suess Effect:</u>

1800-2005 0.019 ‰ yr^{-1}

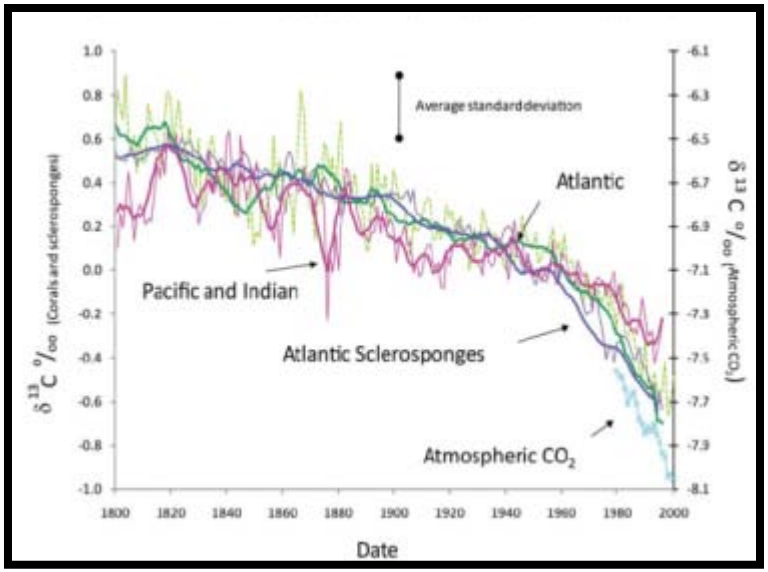
1900-2005 0.036 ‰ yr^{-1}

1960-2005 0.072 ‰ yr^{-1}



Keeling 2005

Results: Stable Isotopes



Swart et al. 2010

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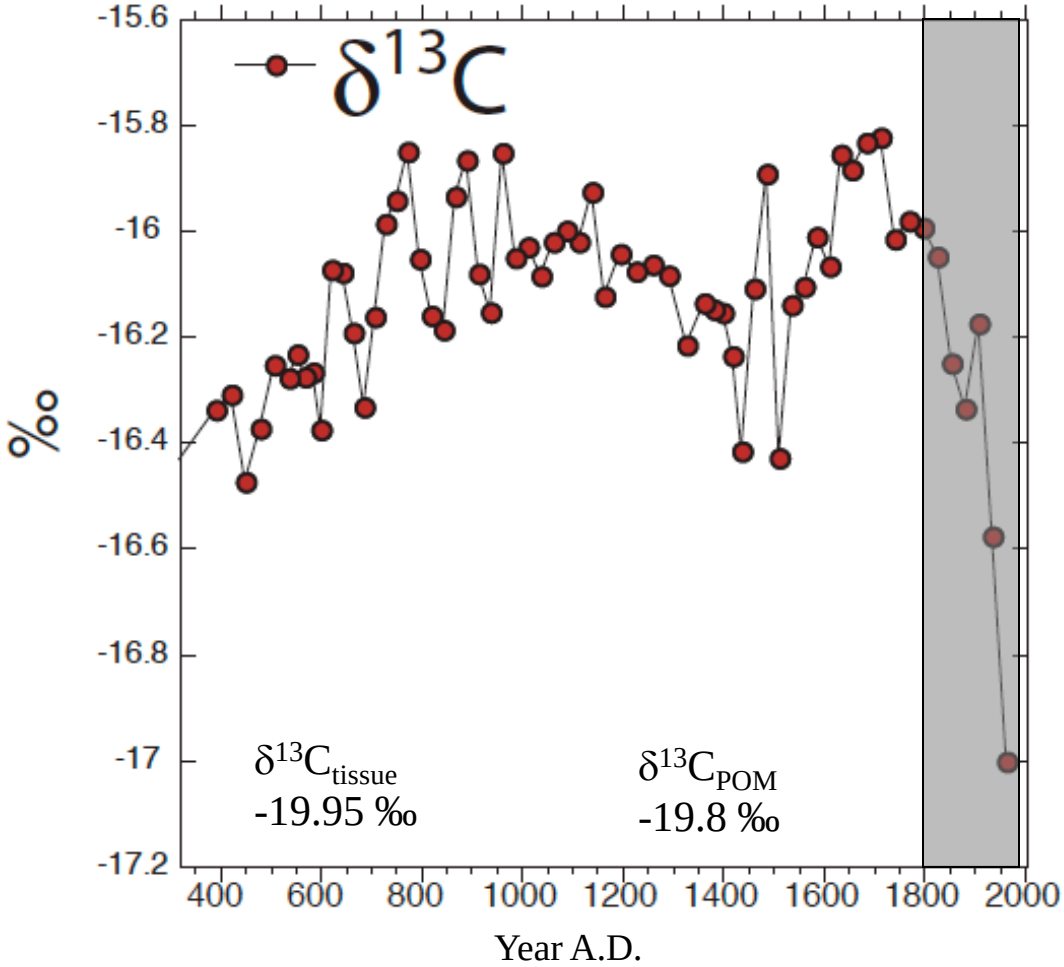

(Demopoulos et al. 2010)

Summary

- ❖Black corals can be accurately dated using ^{14}C analysis; validated through replicate analysis and SEM comparison

- ❖GOM black corals growing continuously for at least the last two millennia, with growth rates ranging from 8 to 22 $\mu m\ yr^{-1}$

- ❖Unlikely renewable in context of fishery management or human life span

- ❖Robust chronologies applied to paleo-climate studies.

- ❖Coupling of $\delta^{15}N$ with Re and I increases suggests recent increase in fluvial nutrient input

- ❖Increased anthropogenic CO_2 input captured in $\delta^{13}C$ record (proxy for CO_2 inventory related to biological pump)

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Pacific Coastal & Marine Science Center
Coastal Ecology and Conservation Research Group

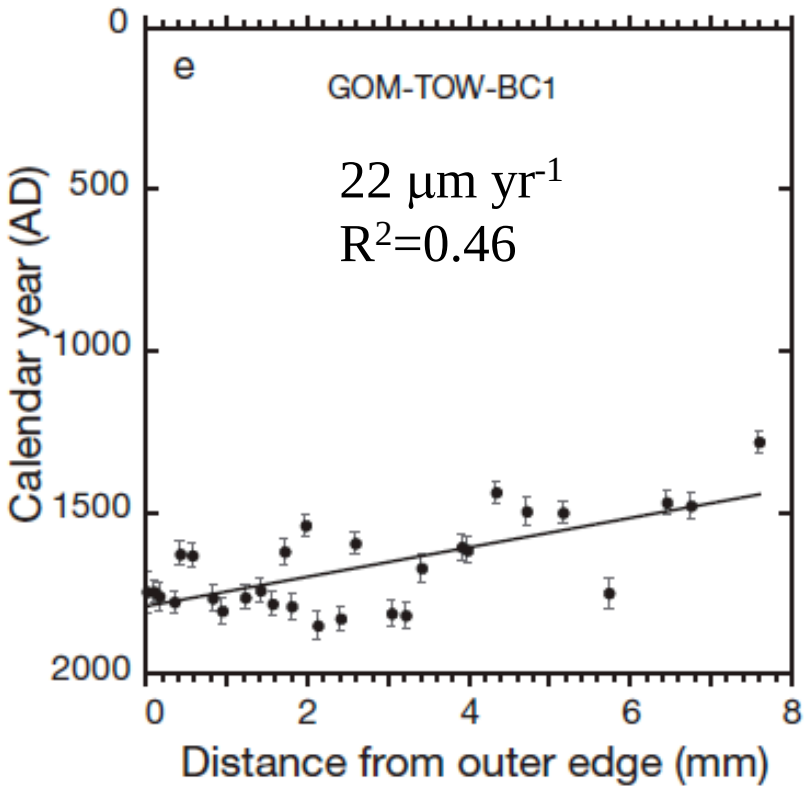
(BOEMRE Environmental Studies Program)

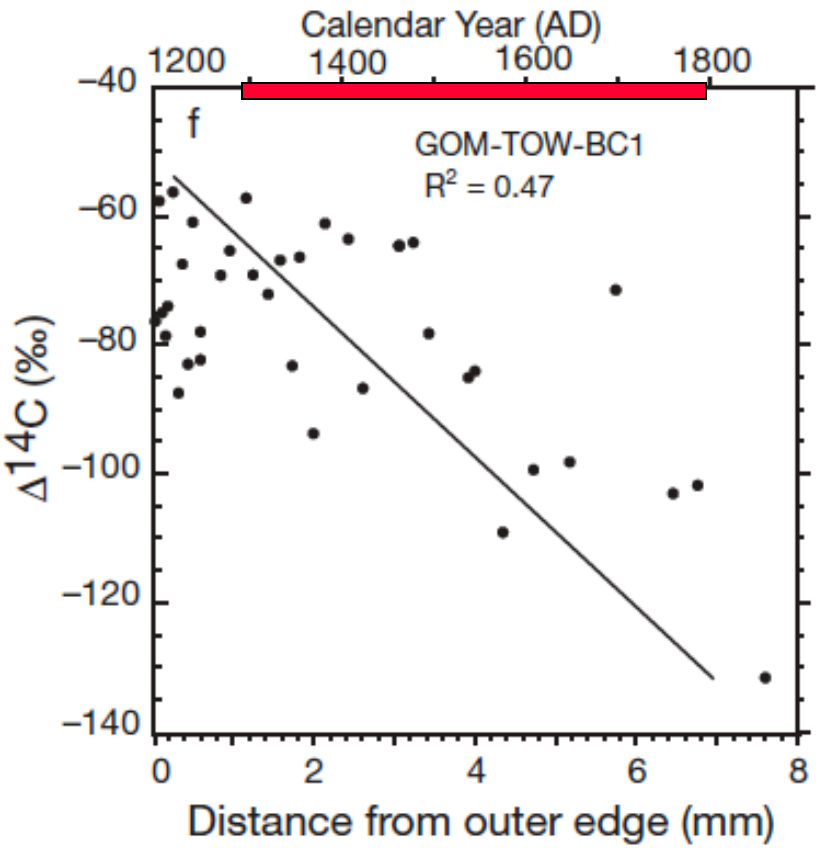
Bureau of Ocean Energy Management, Regulation and Enforcement

NOAA-OE

TAMU
College of Geosciences

Results: Growth Rates





References

Baker, M.S. and C.A. Wilson. 2001. Use of bomb radiocarbon to validate otolith section ages of Red Snapper *Lutjanus campechanus* from the Northern Gulf of Mexico. Limnology and Oceanography 46(7):1819–1824.

Brooks, J.M., M.C. Kennicutt II, C.R. Fisher, S.A. Macko, K. Cole, J.J. Childress, R.R. Bidigare, and R.D. Vetter. 1987. Deep-sea hydrocarbon seep communities: Evidence for energy and nutritional carbon sources. Science 238:1138–1142.

CSA International, Inc. 2007. Characterization of Northern Gulf of Mexico deepwater hard bottom communities with emphasis on *Lophelia* coral. U.S. Department of Interior, Minerals Management Service Gulf of Mexico OCS Region, New Orleans, LA OCS Study MMS 2007-044. 169 pp.

Davies, A.J., G.C.A. Duineveld, T.C.E. van Weering, F.Mienis, A.M. Quattrini, H.E. Seim, J.M. Bane, and S.W. Ross. 2010. Short-term environmental variability in cold-water coral habitat at Viosca Knoll, Gulf of Mexico. Deep Sea Research Part I: Oceanographic Research Papers 57(2):199–212.

References (continued)

Demopoulos, A.W.J. 2011. Personal communication regarding coral tissue. February 1, 2011.

Demopoulos, A.W.J., D. Gualtieri, and K. Kovacs. 2010. Food-web structure of seep sediment macrobenthos from the Gulf of Mexico. Deep Sea Research Part II 57:1972–1981, doi:10.1016/j.dsr2.2010.05.011.

Druffel, E.R.M., S. Griffin, A. Witter, E. Nelson, J. Southon, M. Kashgarian, and J. Vogel. 1995. *Gerardia*: Bristlecone pine of the deep-sea? Geochimica et Cosmochimica Acta, 59(23):5031–5036.

Goldberg, W., T.L. Hopkins, S.M. Holl, J. Schaefer, K.J. Kramer, T.D. Morgan, and K. Kim. 1994. Chemical composition of the sclerotized black coral skeleton (Coelenterata: Antipatharia): A comparison of two species. Comparative Biochemistry and Physiology(107B):633–643.

Keeling, C.D., S.C. Piper, R.B. Bacastow, M. Wahlen, T.P. Whorf, M. Heimann, and H.A. Meijer. 2005. Atmospheric CO_2 and $^{13}CO_2$ exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In: Ehleringer, J.R., T.E. Cerling, and M.D. Dearing, eds. A History of Atmospheric CO_2 and Its Effects on Plants, Animals, and Ecosystems. New York: Springer Verlag. Pp. 83–113.

References (continued)

Key, R.M. 2001. Ocean process tracers: Radiocarbon. In: Steele, J., S. Thorpe, and K. Turekian, eds. Encyclopedia of Ocean Sciences. London: Academic Press, Ltd. Pp. 2338–2353.

Oktay, S.D., P.H. Santschi, J.E. Moran, and P. Sharma. 2001. ^{129}I and ^{127}I transport in the Mississippi River. Environmental Science and Technology 35:4470–4476.

Paull, C.K., B. Hecker, R. Commeau, R.P. Freeman-Lynde, A.C. Neumann, W.P. Corso, S. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at the Florida Escarpment resemble hydrothermal vent communities. Science 226:965–967.

Prouty, N.G., E.B. Roark, N.A. Buster, and S.W. Ross. 2011. Growth-rate and age distribution of deep-sea black corals in the Gulf of Mexico. Marine Ecology Progress Series 423:101–115.

Rahaman, W. and S.K. Singh. 2010. Rhenium in rivers and estuaries of India: Sources, transport and behaviour. Marine Chemistry 118:1–10.

Roark, E.B., T.P. Guilderson, R.B. Dunbar, S.J. Fallon, and D.A. Mucciarone. 2009. Extreme longevity in proteinaceous deep-sea corals. Proceedings of the National Academy of Sciences 106(13): 5204–5208.

References (continued)

Sulak, K.J., M.T. Randall, K.E. Luke, A.D.Norem, and J.M. Miller, eds. 2008. Characterization of Northern Gulf of Mexico deepwater hard bottom communities with emphasis on *Lophelia* coral – *Lophelia* reef megafaunal community structure, biotopes, genetics, microbial ecology, and geology. USGS Open-File Report 2008-1148; OCS Study MMS 2008-115.

Swart, P.K., L. Greer, B.E. Rosenheim, C.S. Moses, A.J. Waite, A. Winter, R.E. Dodge, and K. Helmle. 2010. The ^{13}C Suess effect in scleractinian corals mirror changes in the anthropogenic CO_2 inventory of the surface oceans. Geophysical Research Letters 37:L05604, doi: 10.1029/2009GL041397.

Vander Zanden, M.J. and J.B. Rasmussen. 2001. Variation in $d^{15}N$ and $d^{13}C$ trophic fractionation: Implications for aquatic food web studies. Limnology and Oceanography 46(8):2061–206.

Wagner, A.J. 2009. Oxygen and carbon isotopes and coral growth in the Gulf of Mexico and Caribbean Sea as environmental and climate indicators. Ph.D. dissertation, Texas A&M University. 117 pp.

References (continued)

Wagner, A.J. 2009. Oxygen and carbon isotopes and coral growth in the Gulf of Mexico and Caribbean Sea as environmental and climate indicators. Ph.D. dissertation, Texas A&M University. 117 pp.

Wagner, A.J., T.P. Guilderson, N. Slowey, and J.E. Cole. 2009. Pre-Bomb surface water radiocarbon of the Gulf of Mexico and Caribbean as recorded in hermatypic corals. Radiocarbon 51(3):947–954.

Williams, B., M.J. Risk, S.W. Ross, and K.J. Sulak. 2006. Deep-water antipatharians: Proxies of environmental change. Geology 34:773–776.