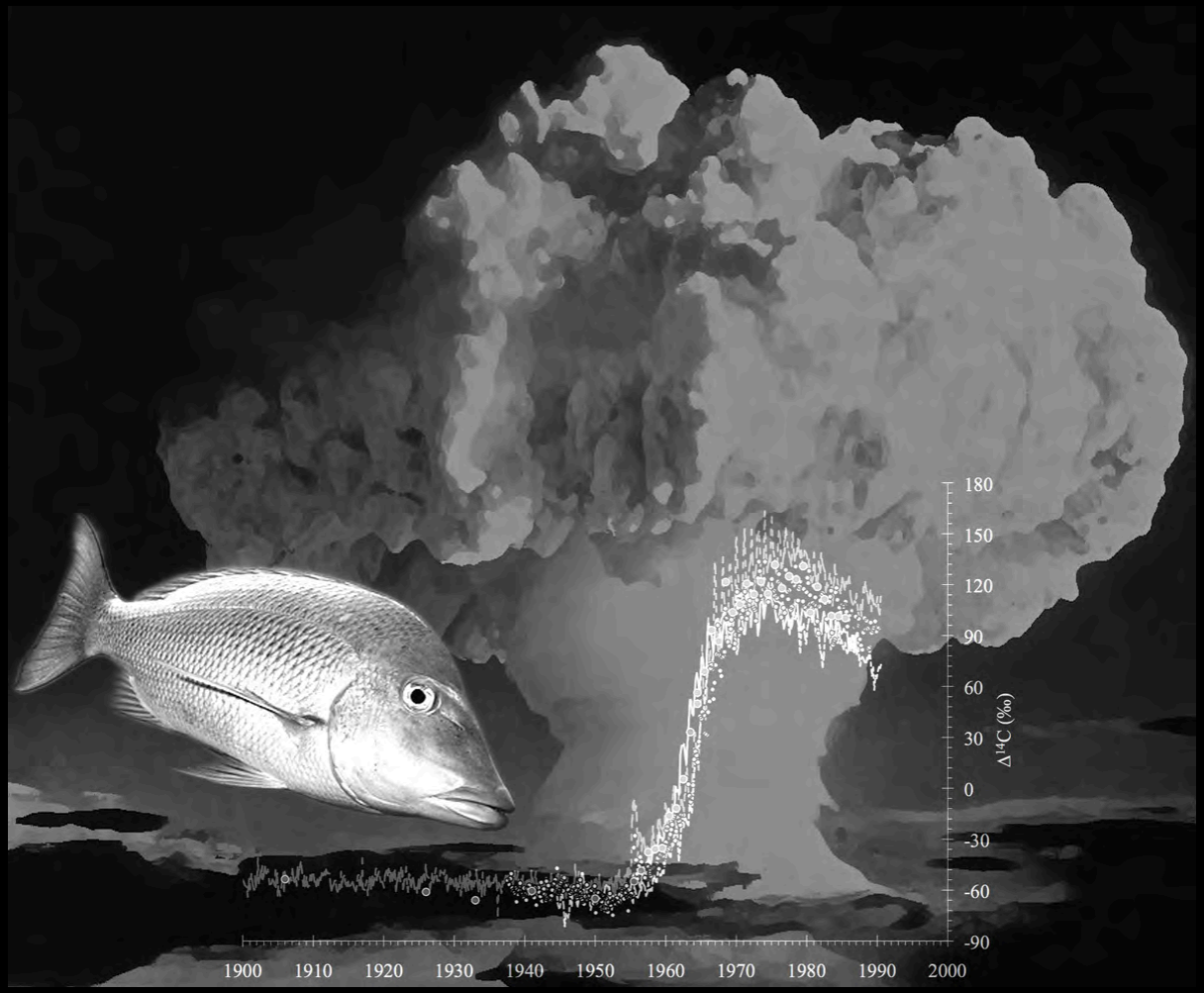
Nuclear bombs and coral: Guam coral core reveals operation-specific radiocarbon signals from the Pacific Proving Grounds



Allen H. Andrews & Donald Kobayashi
NOAA Fisheries – PIFSC

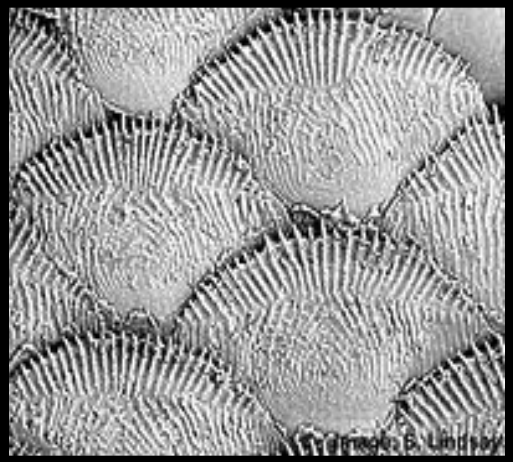
Ryuji Asami & Yasufumi Iryu
University of the Ryukyus

Frank Camacho
University of Guam

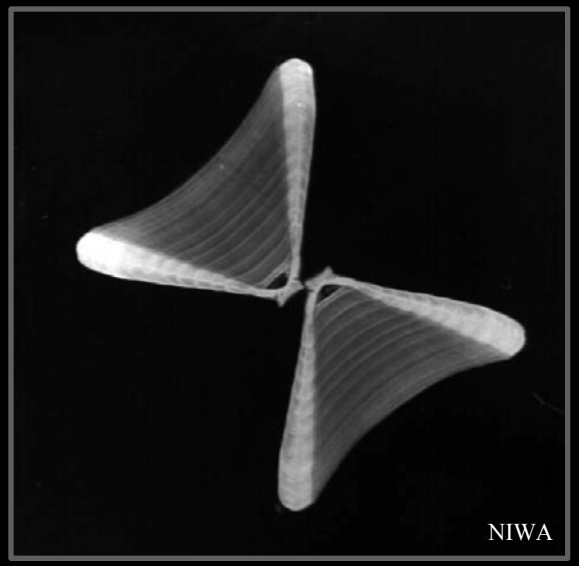
… Including numerous other colleagues involved in the fish age and growth work presented here.

Age estimation of fishes

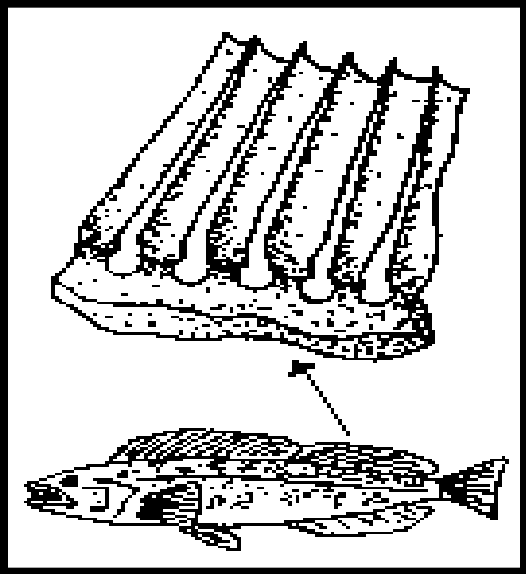
Scales

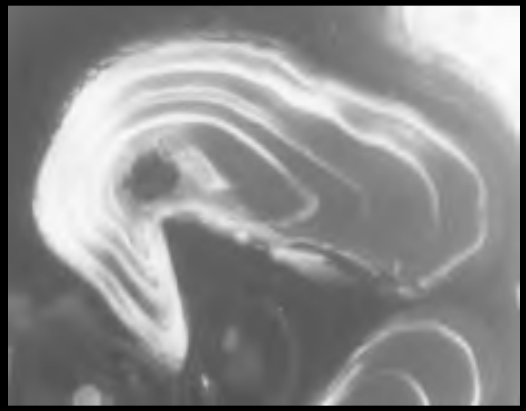


Vertebrae

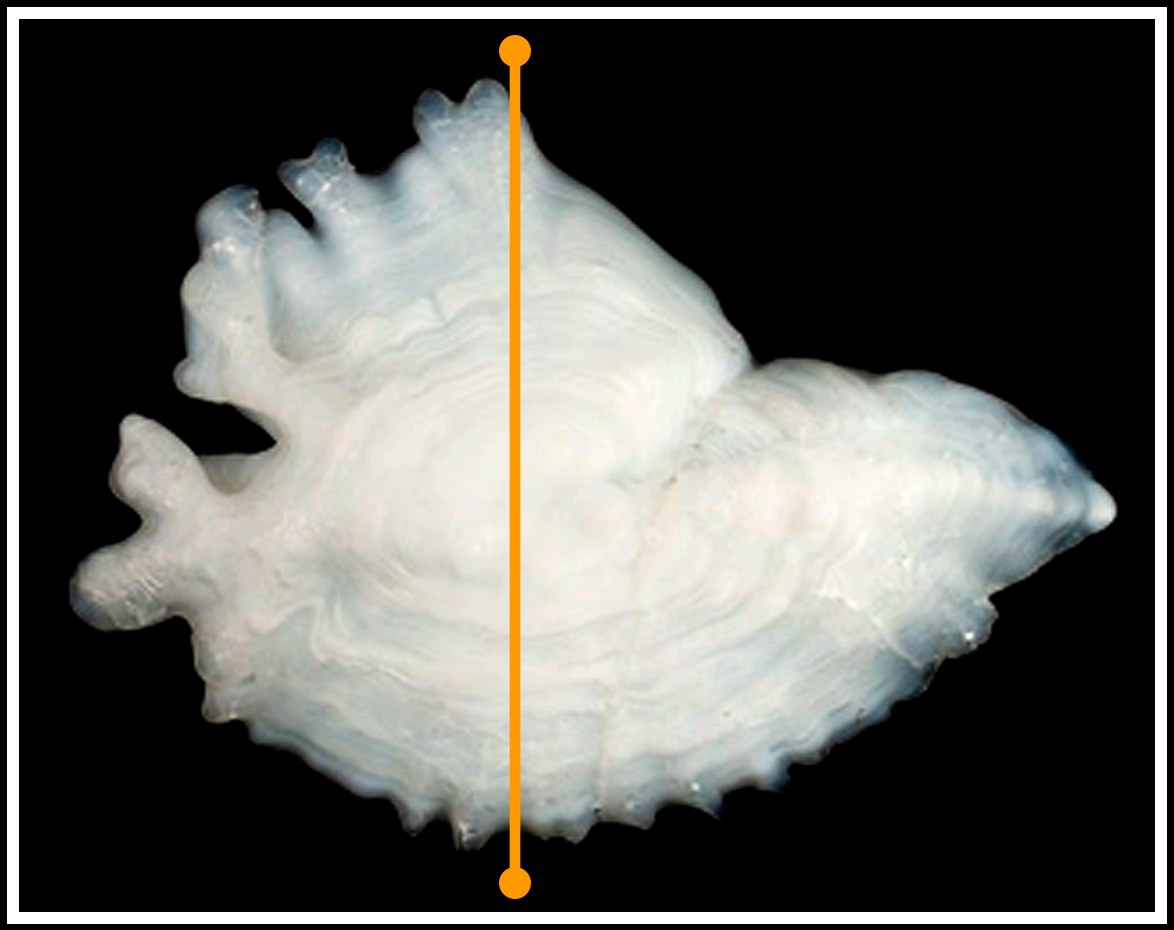


Fin rays





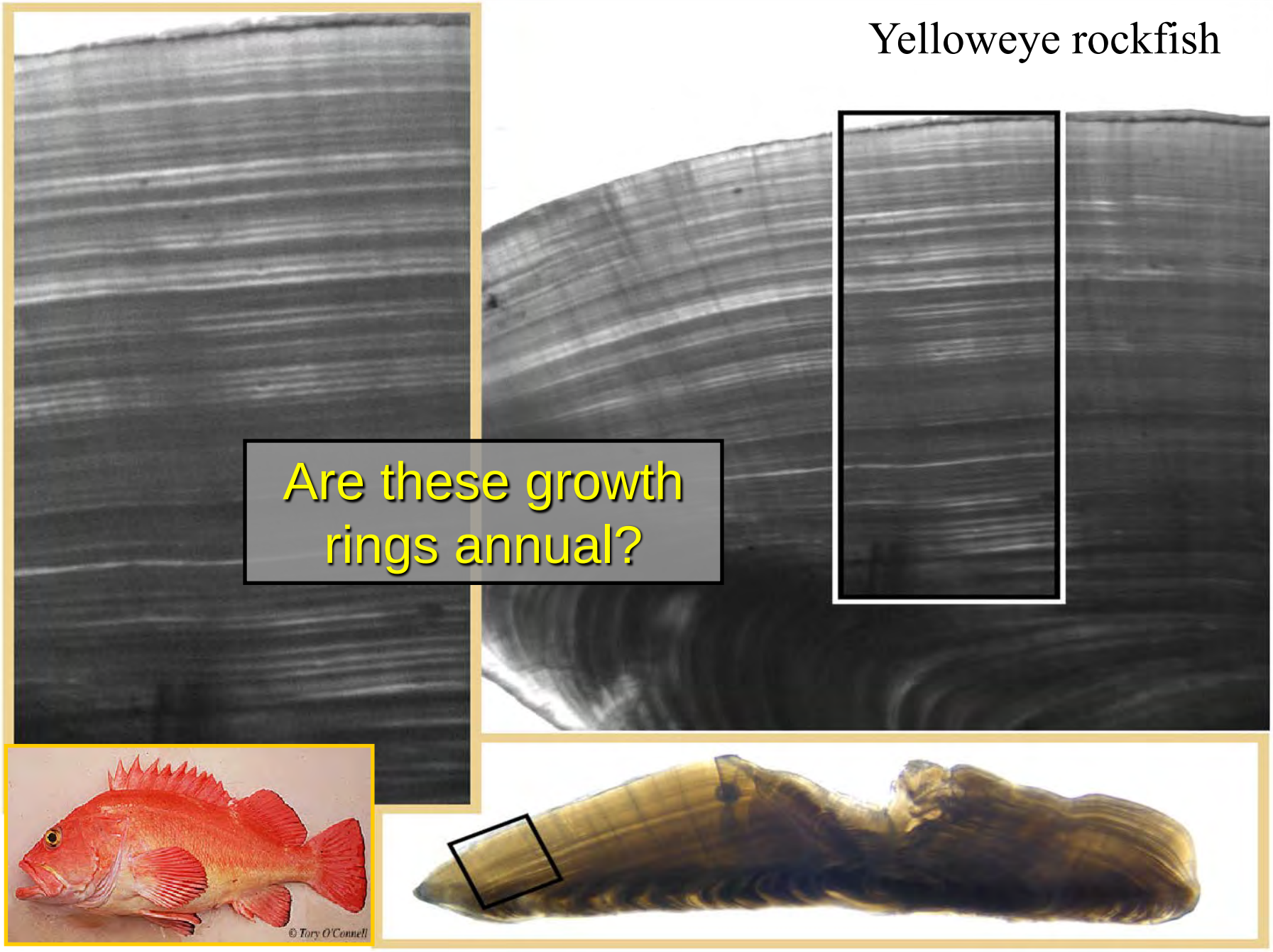
Fish age from Otoliths



Shortraker rockfish (*Sebastes borealis)*

Estimated to be
>100 years old…

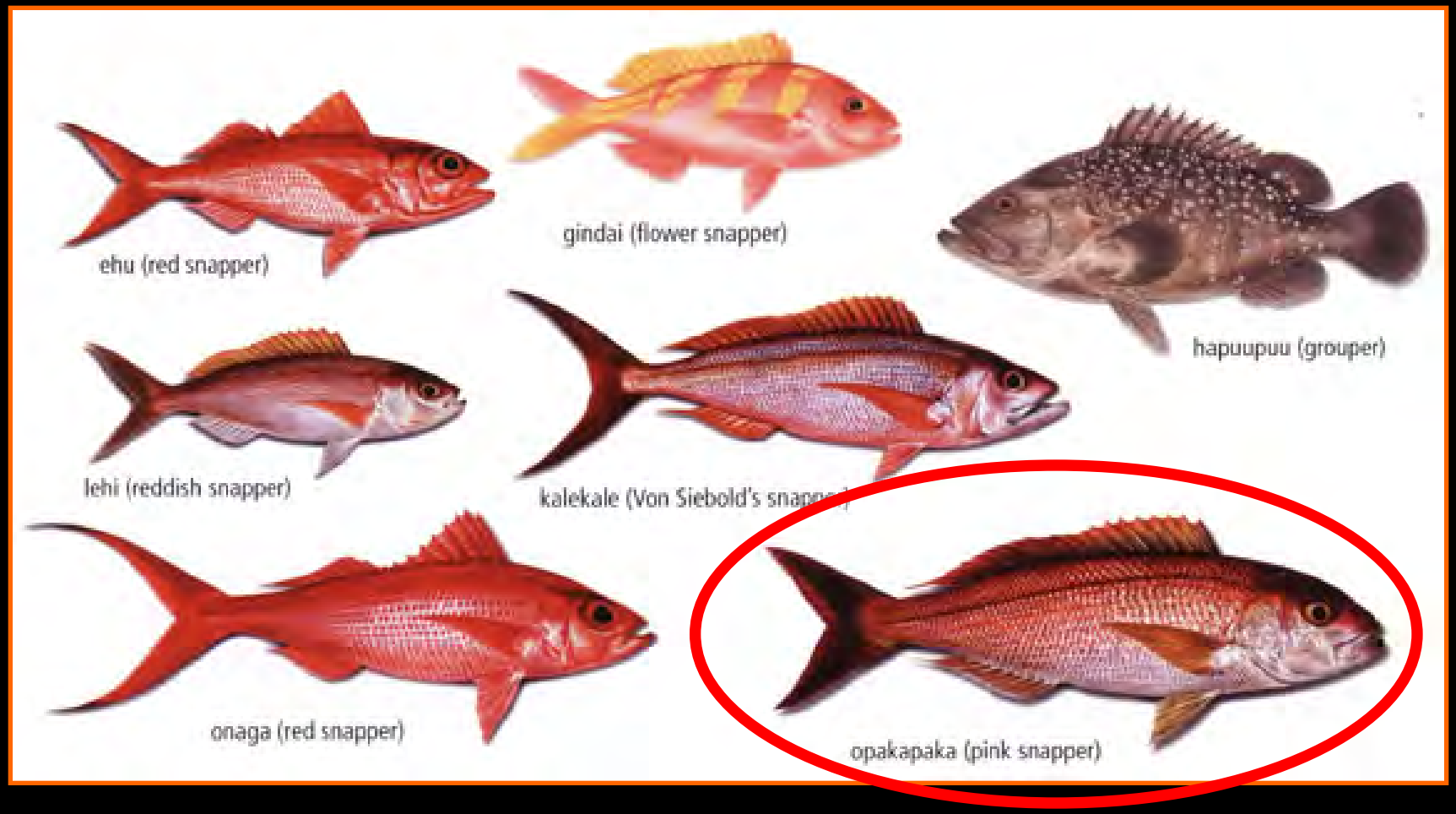
Yelloweye rockfish



Bomb Radiocarbon Dating

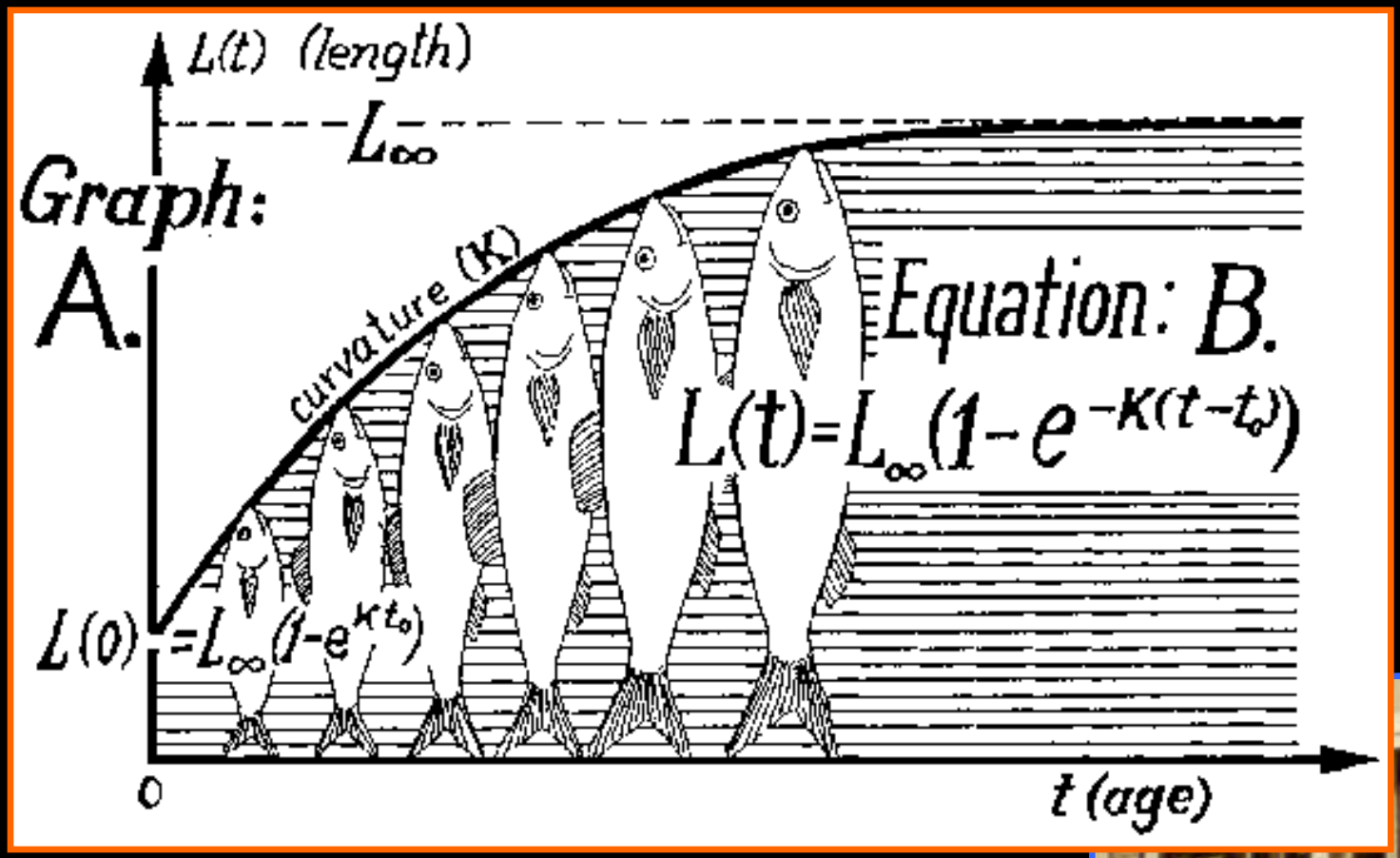
Theory and Application

Opakapaka (*Pristipomoides filamentosus)*



Age validation of this fish using Bomb Radiocarbon Dating

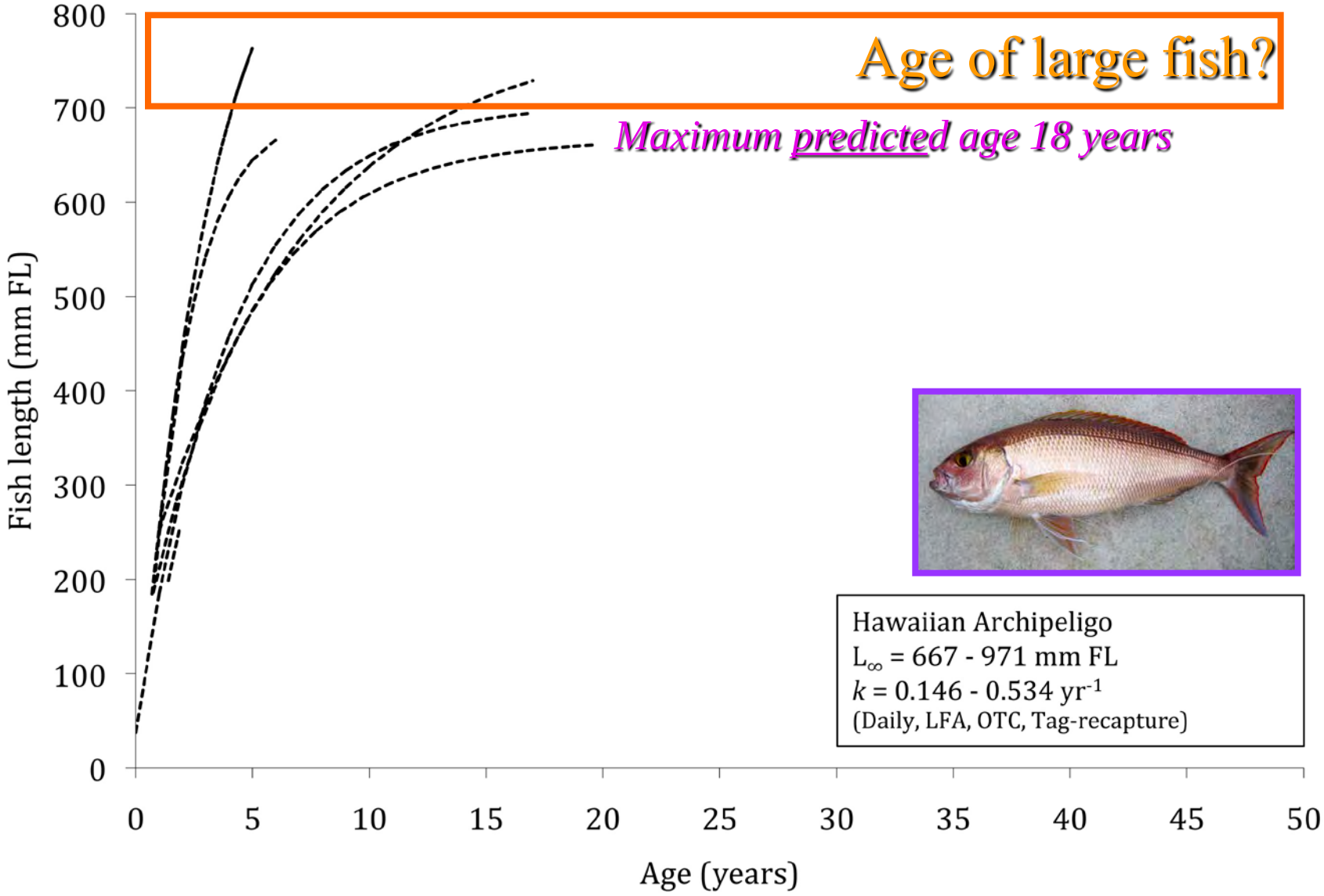
Von Bertalanffy Growth Function



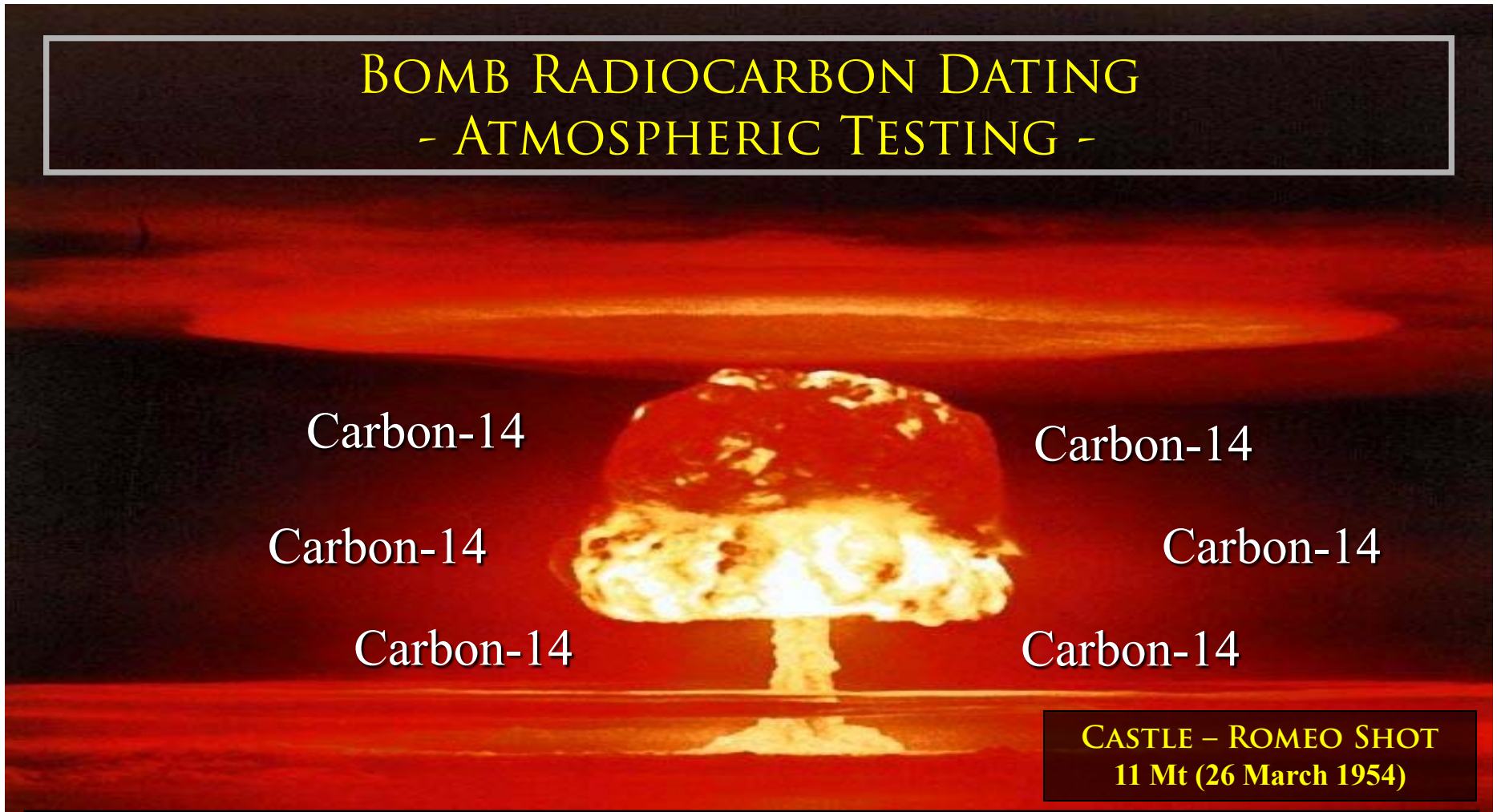
How fish grow over time

Important to stock assessments

Von Bertalanffy Growth Functions – Age estimation and extrapolation



Bomb Radiocarbon Dating
- Atmospheric Testing -



Castle – Romeo Shot
11 Mt (26 March 1954)

Thermonuclear detonations reached *megatons* of TNT in energy equivalence from the mid-1950s to early-1960s

Testing created a global radiocarbon signal and doubled the naturally occurring levels in the atmosphere

Atmospheric bomb radiocarbon records

Vermunt, Austria 47°N, 10°E
Schauinsland, Germany 48°N, 8°E
Debre Zeit, Ethiopia 9°N, 39°E
Wellington, New Zealand 41°S, 175°E
Cape Grim, Australia 41°S, 145°E
Atmospheric nuclear tests in the SH
Atmospheric nuclear tests in the NH

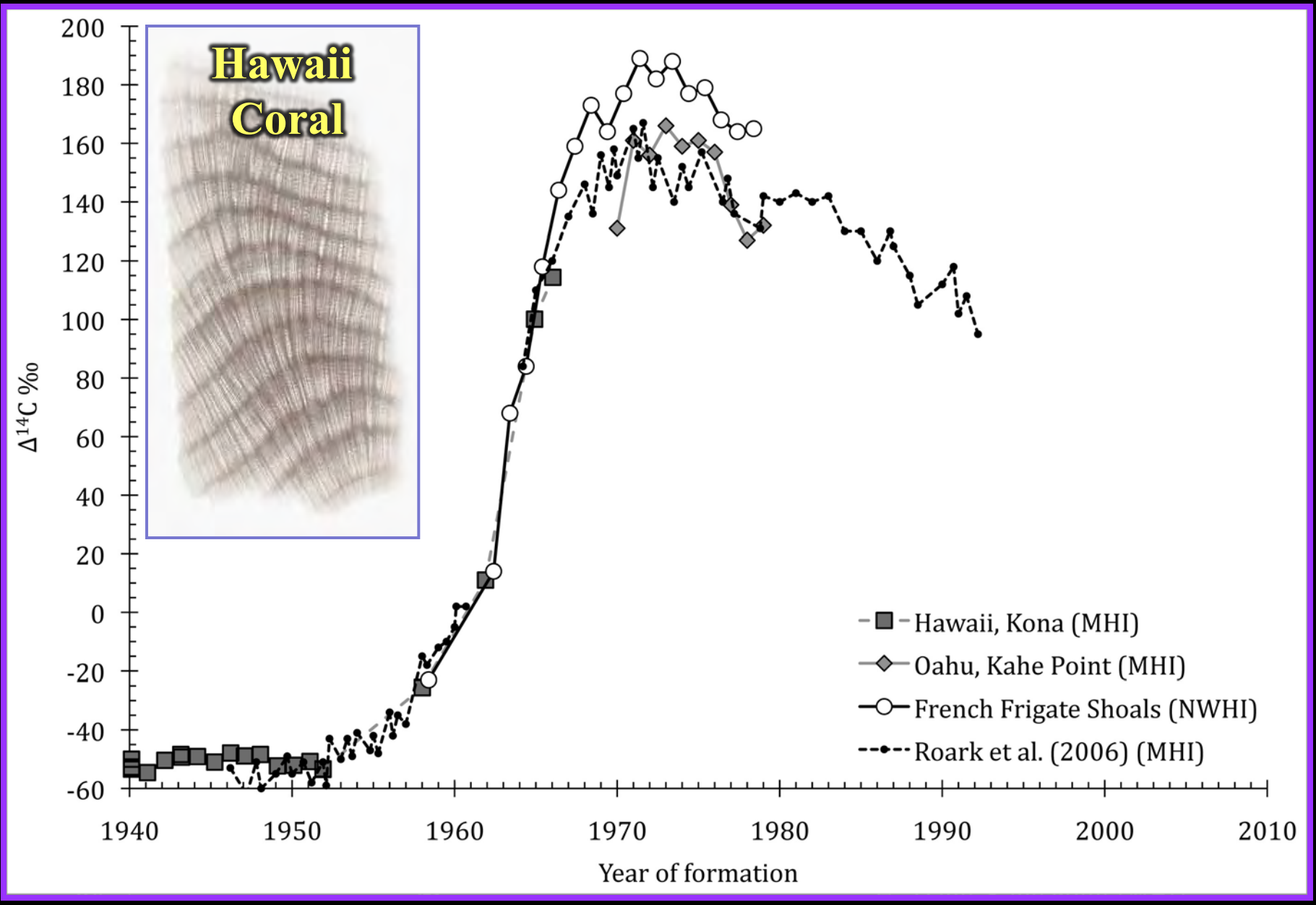
$\Delta^{14}C$ (‰)

Effective yield TNT (Mt)

Year (AD)

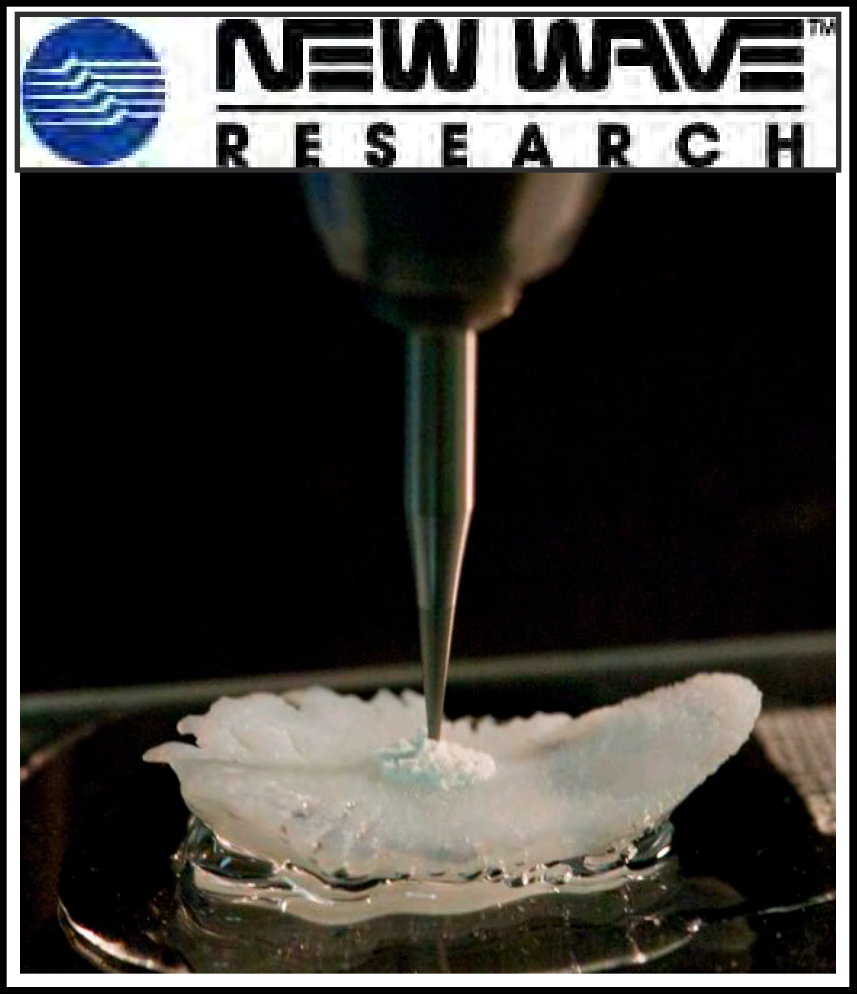
Hua and Barbetti (2004)

Marine Bomb Radiocarbon Records



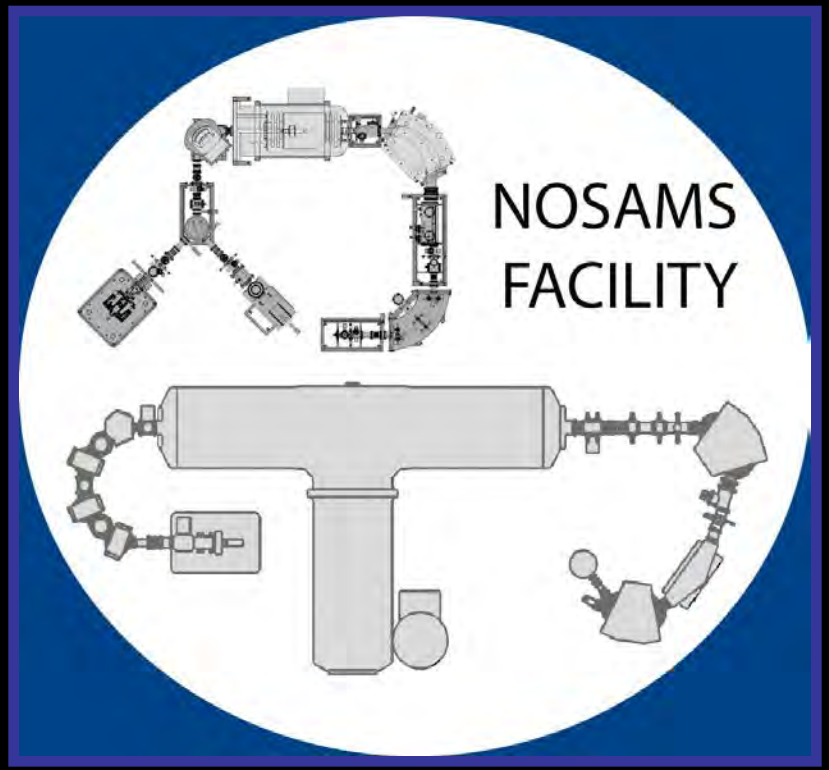
Opakapaka otolith

Pink Hawaiian snapper – Ear stone

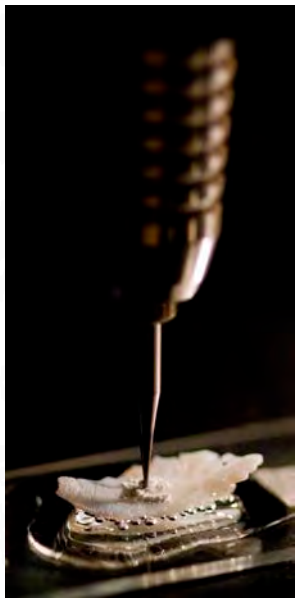


Series of extractions
Dimensions within 1 yr otolith
Yield ~3 mg of material

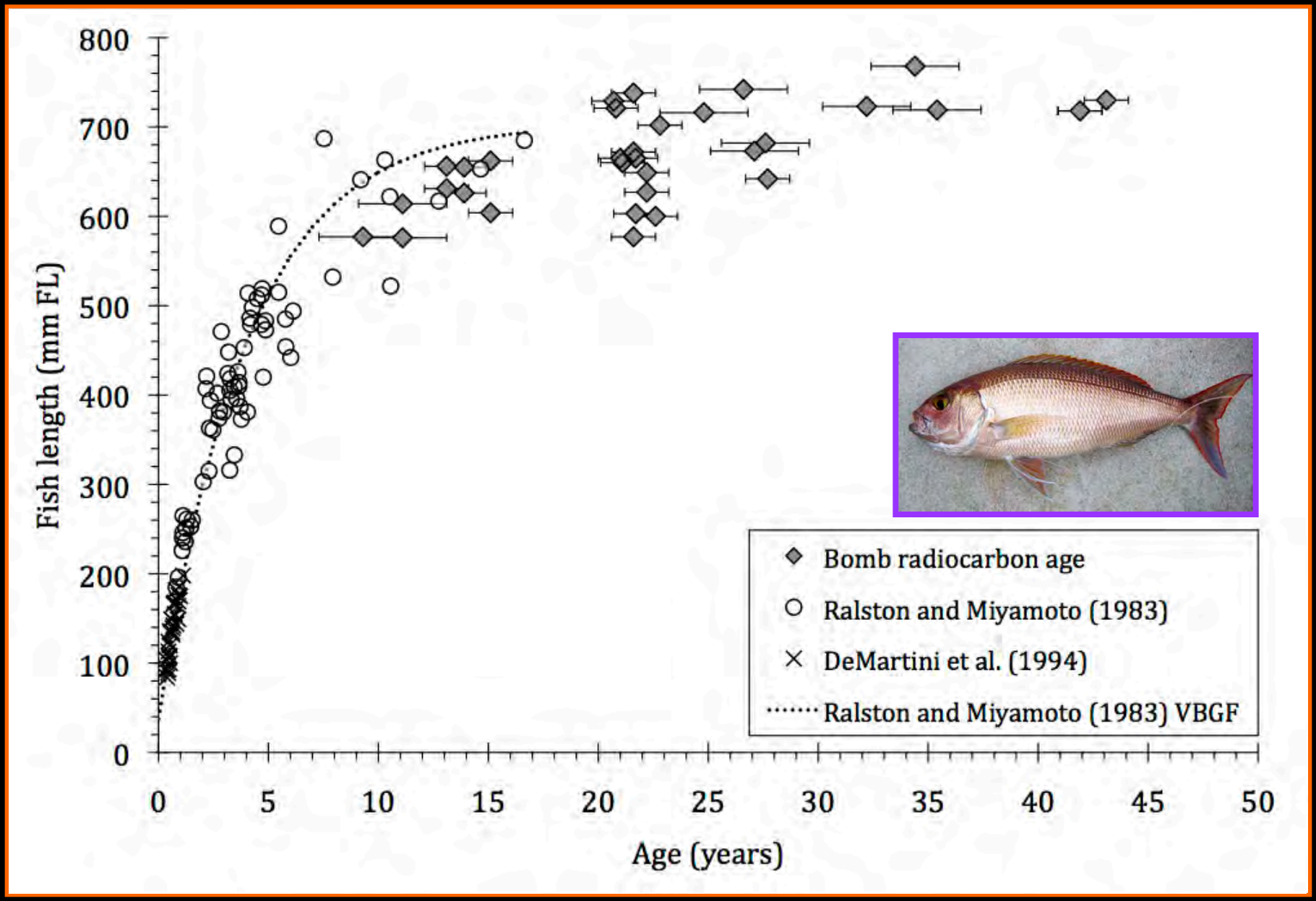
Radiocarbon Analysis -
$\Delta^{14}C$ ‰ at Woods Hole Oceanographic Institute



Opakapaka Bomb Radiocarbon dating



Von Bertalanffy Growth Functions & New age data



Published - Canadian Journal of Fisheries and Aquatic Sciences

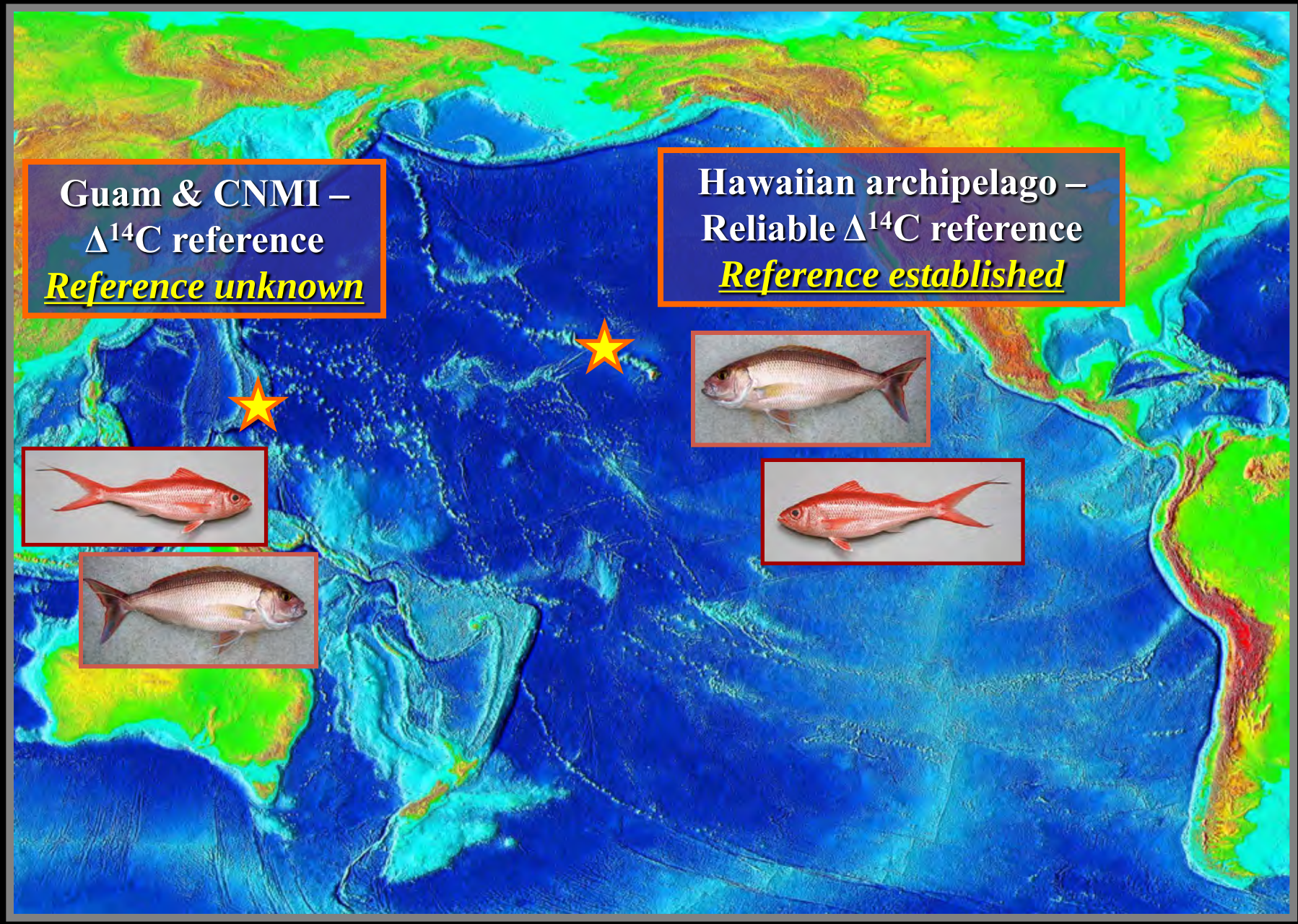
A long-lived life history for a tropical, deepwater snapper (*Pristipomoides filamentosus*): bomb radiocarbon and lead–radium dating as extensions of daily increment analyses in otoliths

Allen H. Andrews, Edward E. DeMartini, Jon Brodziak, Ryan S. Nichols, and Robert L. Humphreys

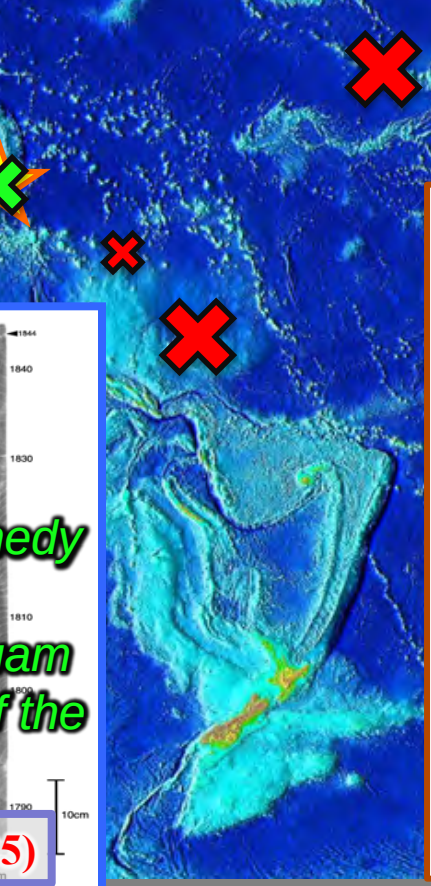
Abstract: Growth characteristics of *Pristipomoides filamentosus*, a deepwater eteline snapper of major economic importance, are incomplete and inconsistent across its geographical range. Early growth rates have been validated using daily increment and length–frequency analyses, but historical estimates of adult growth rates are variable and longevity is unknown. Studies of *P. filamentosus* in the Hawaiian Islands have cautioned against unjustified estimates of longevity, but 18 years has at times been uncritically assumed as the maximum age. The present study addresses these age, growth, and longevity issues using lead–radium and bomb radiocarbon dating by providing valid age estimates for adult *P. filamentosus*. Valid length-at-age estimates ranged from approximately 10 years to more than 40 years. These data, together with robust daily increment data, were used to model a fully validated, long-lived life history for *P. filamentosus*. This study adds to the few existing studies supporting a view that many tropical fishes, particularly deepwater species, can be longer lived than previously surmised.

Contact me for PDF – Allen.Andrews@noaa.gov

Regional Age Validation

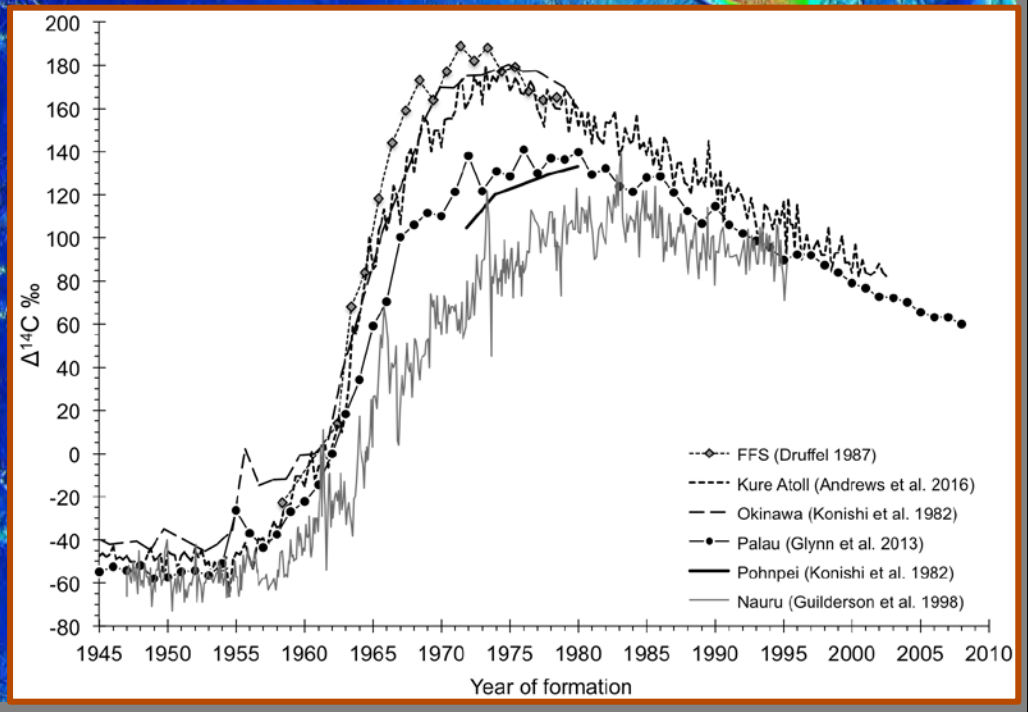


Guam - Bomb Radiocarbon Record?

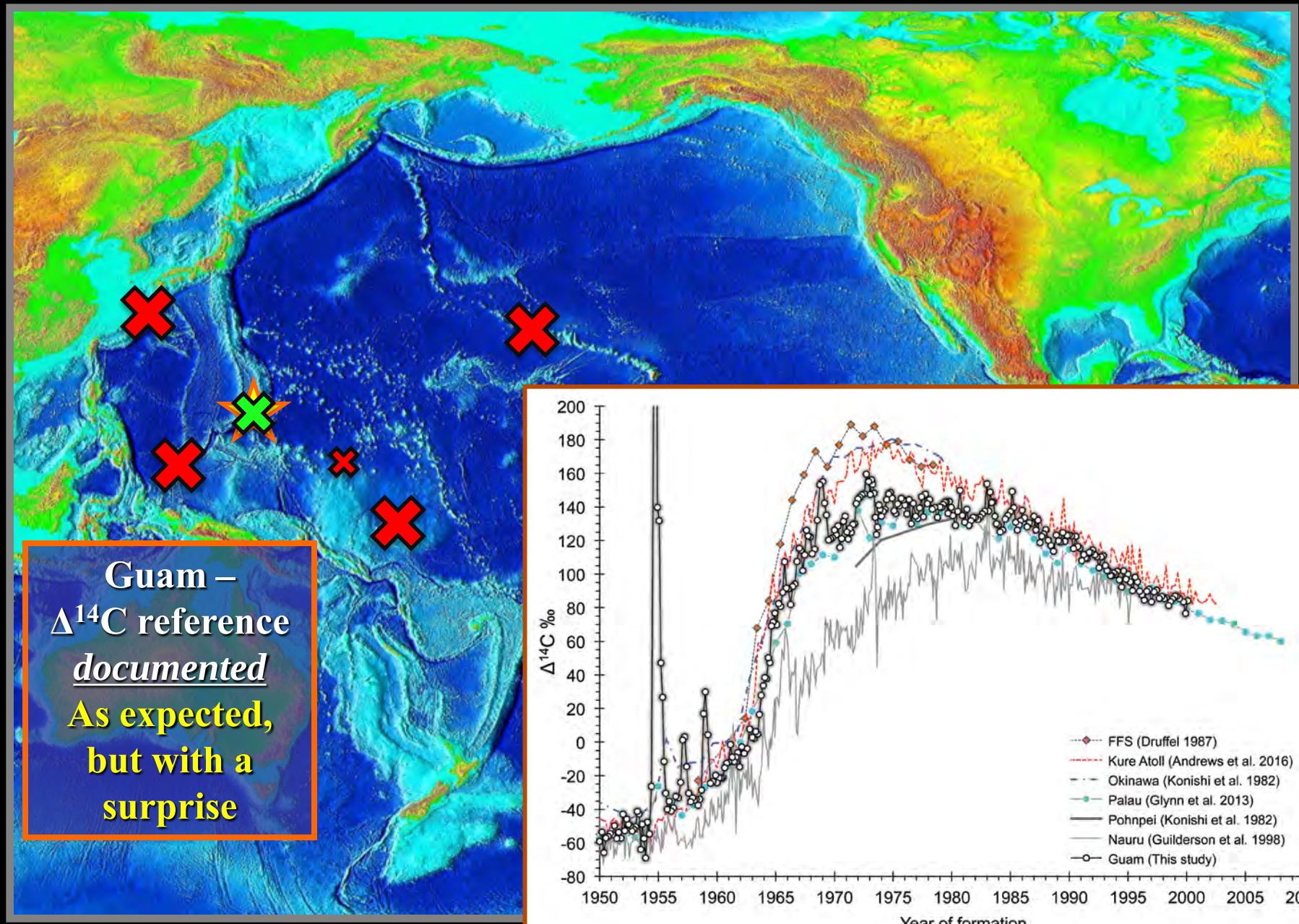


Saltonstall-Kennedy funding with University of Guam and University of the Ryukyus

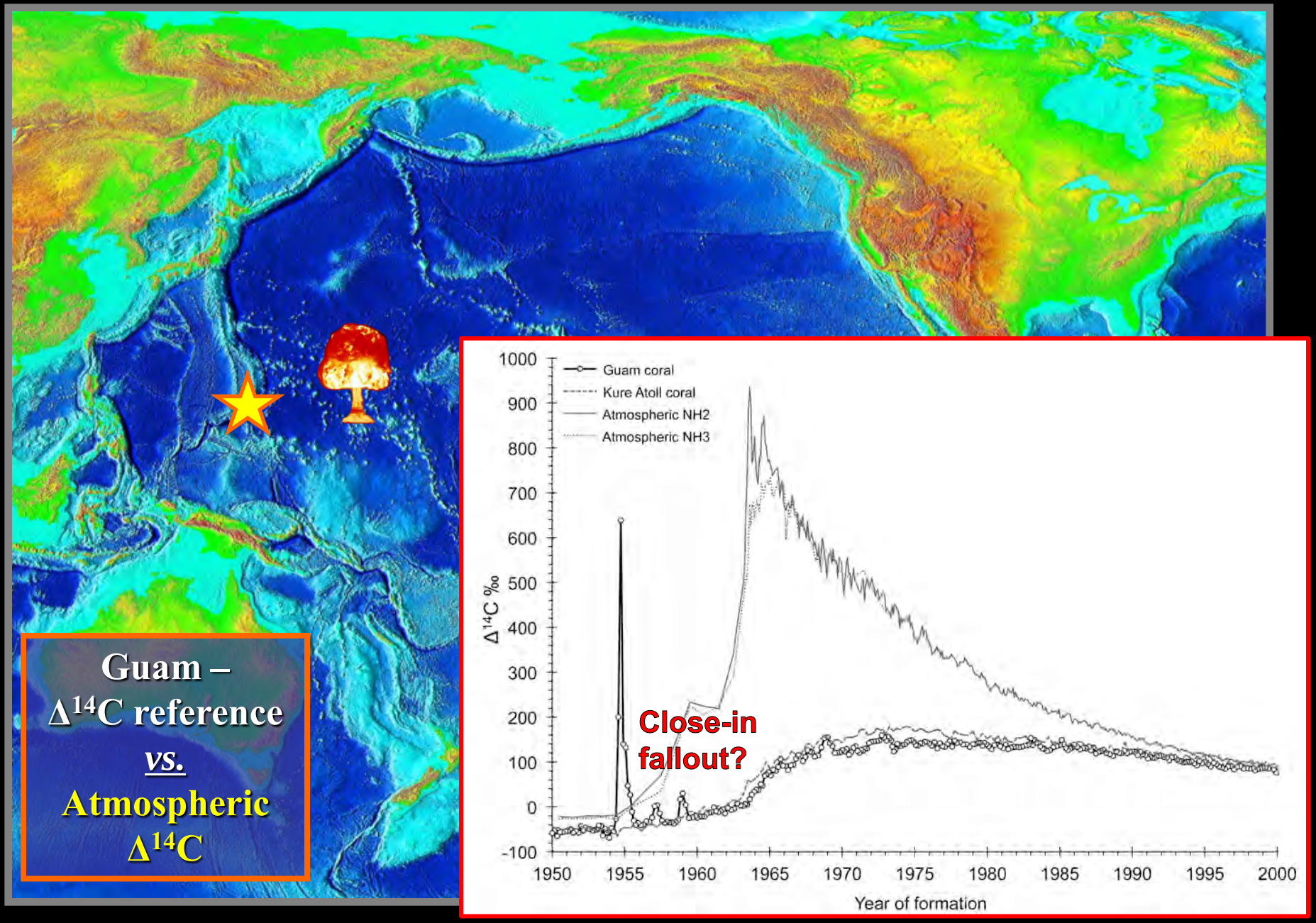
Asami et al. (2005)



Guam & Regional Bomb Radiocarbon Records

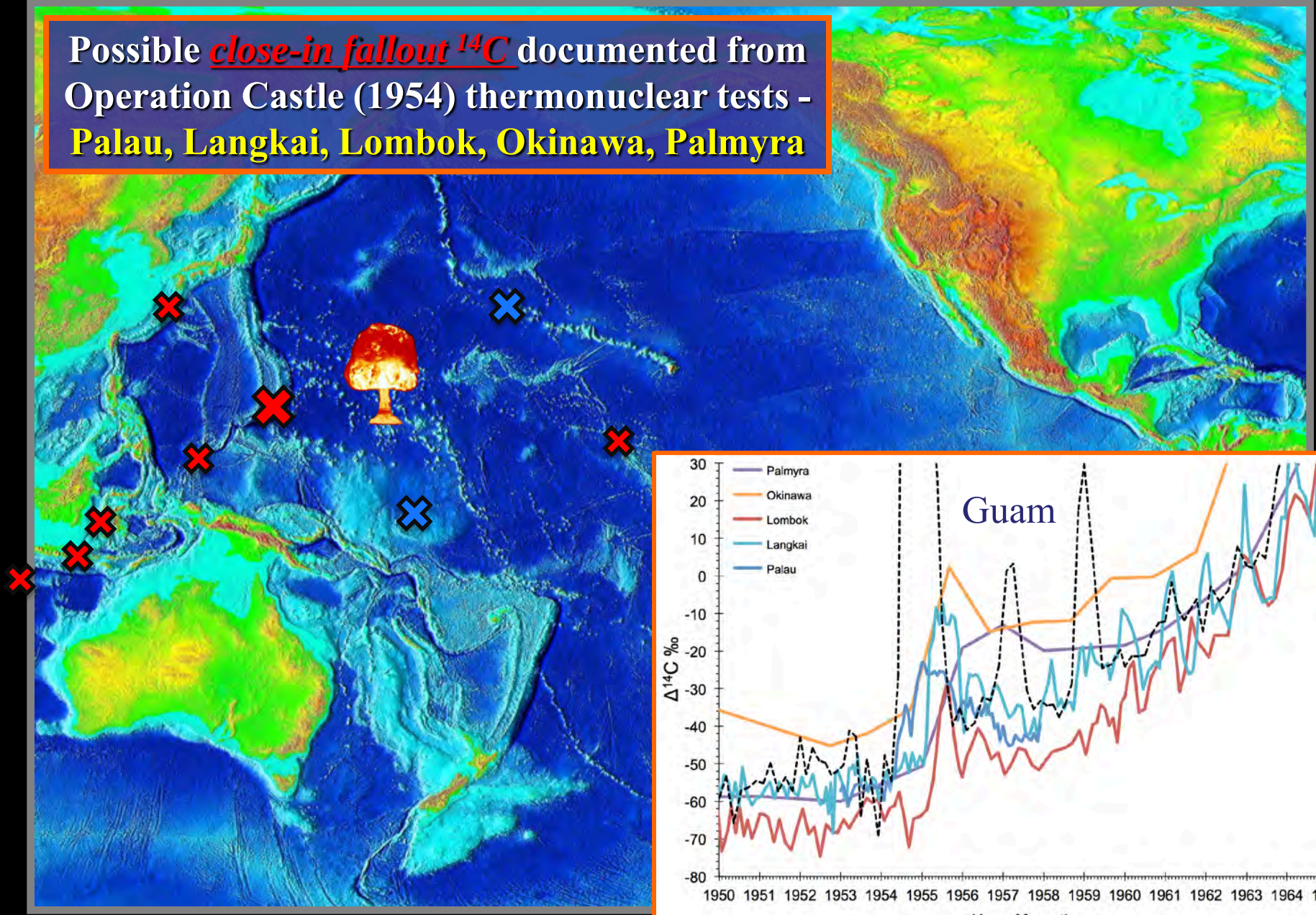


Guam - Early Bomb Radiocarbon

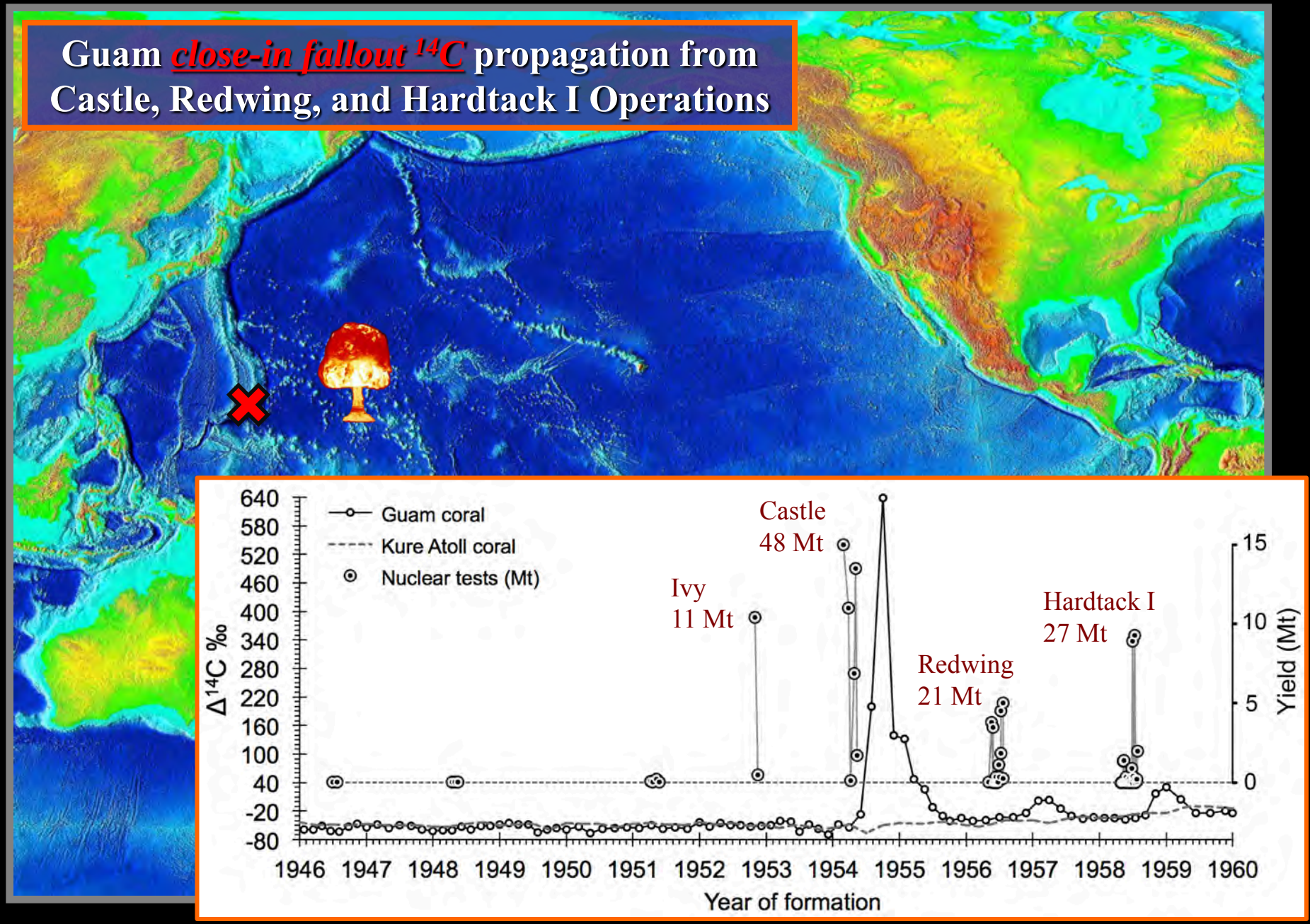


Indo-Pacific Early Bomb Radiocarbon

Possible *close-in fallout* ^{14}C documented from Operation Castle (1954) thermonuclear tests - Palau, Langkai, Lombok, Okinawa, Palmyra

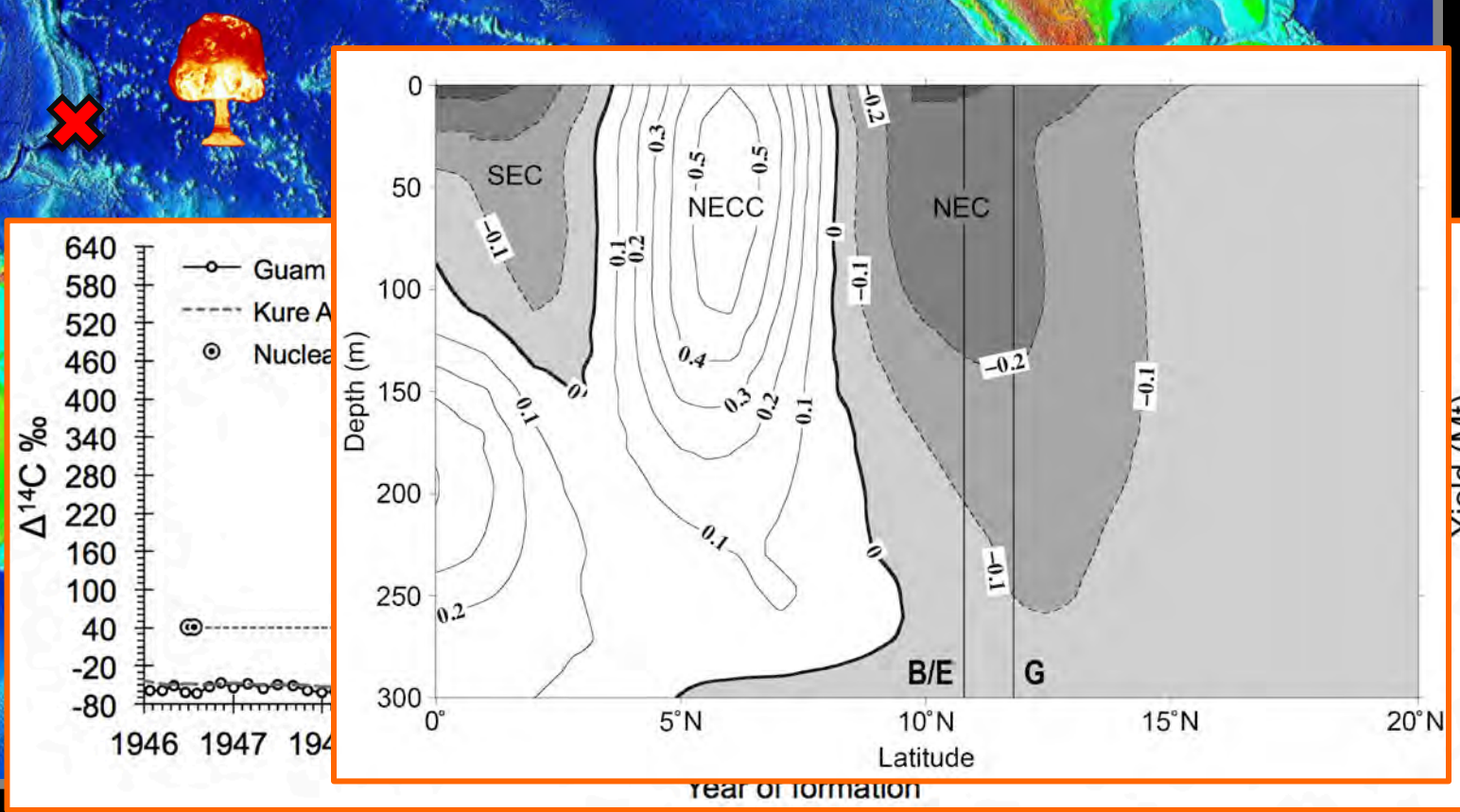


Guam Early Bomb Radiocarbon



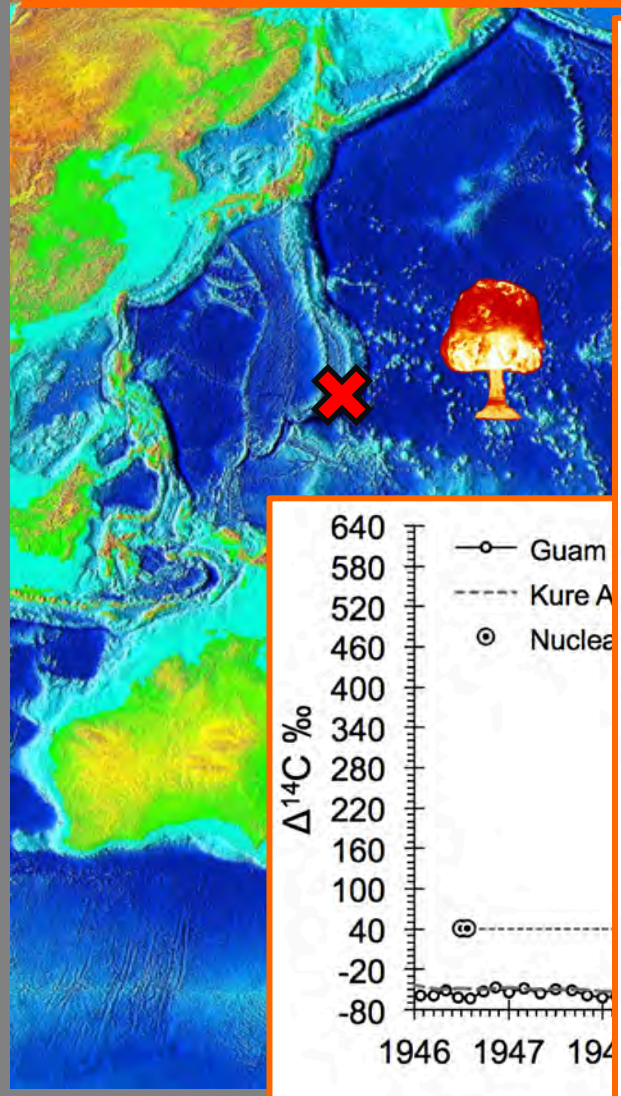
Guam Early Bomb Radiocarbon

Guam *close-in fallout* ^{14}C propagation from Castle, Redwing, and Hardtack I Operations



Guam Early Bomb Radiocarbon

Guam *close-in fallout* ^{14}C propagation from Castle, Redwing, and Hardtack I Operations



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Reconstructing surface ocean circulation with ^{129}I time series records from corals

Ching-Chih Chang [a, b, *], George S. Burr [a, c], A.J. Timothy Jull [a, b], Joellen L. Russell [b], Dana Biddulph [a], Lara White [a], Nancy G. Prouty [d], Yue-Gau Chen [e], Chuan-Chou Shen [e], Weijian Zhou [f], Doan Dinh Lam [g]

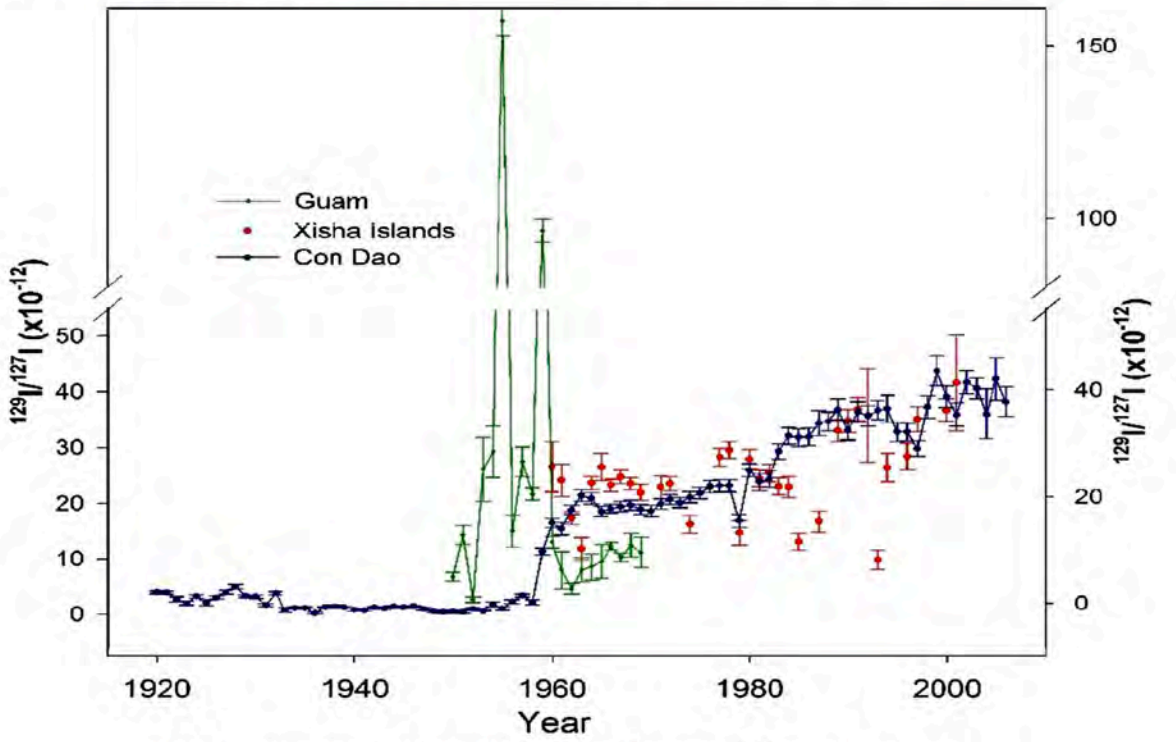
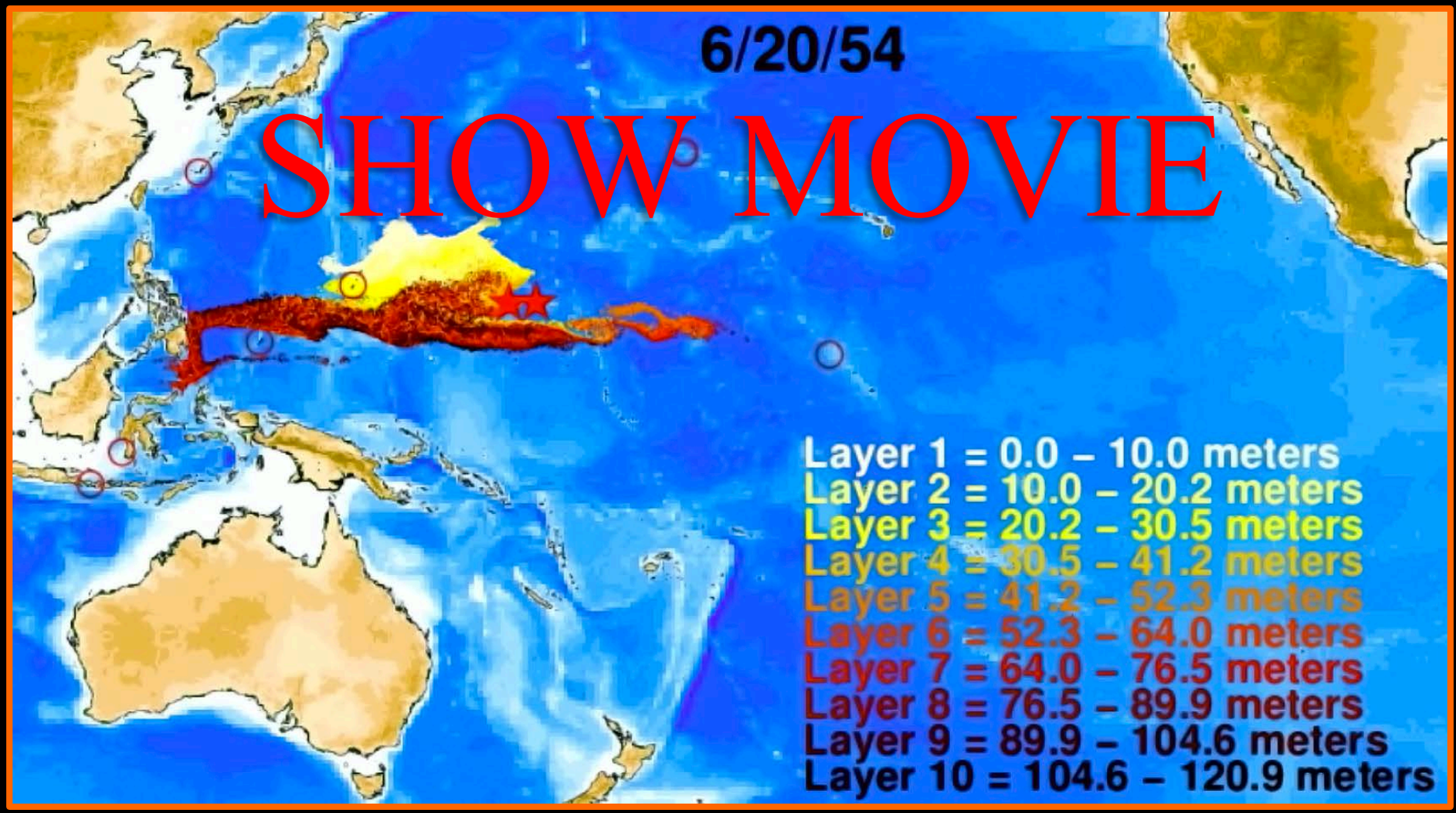


Fig. 4. Con Dao, Xisha Islands and Guam ^{129}I coral records.

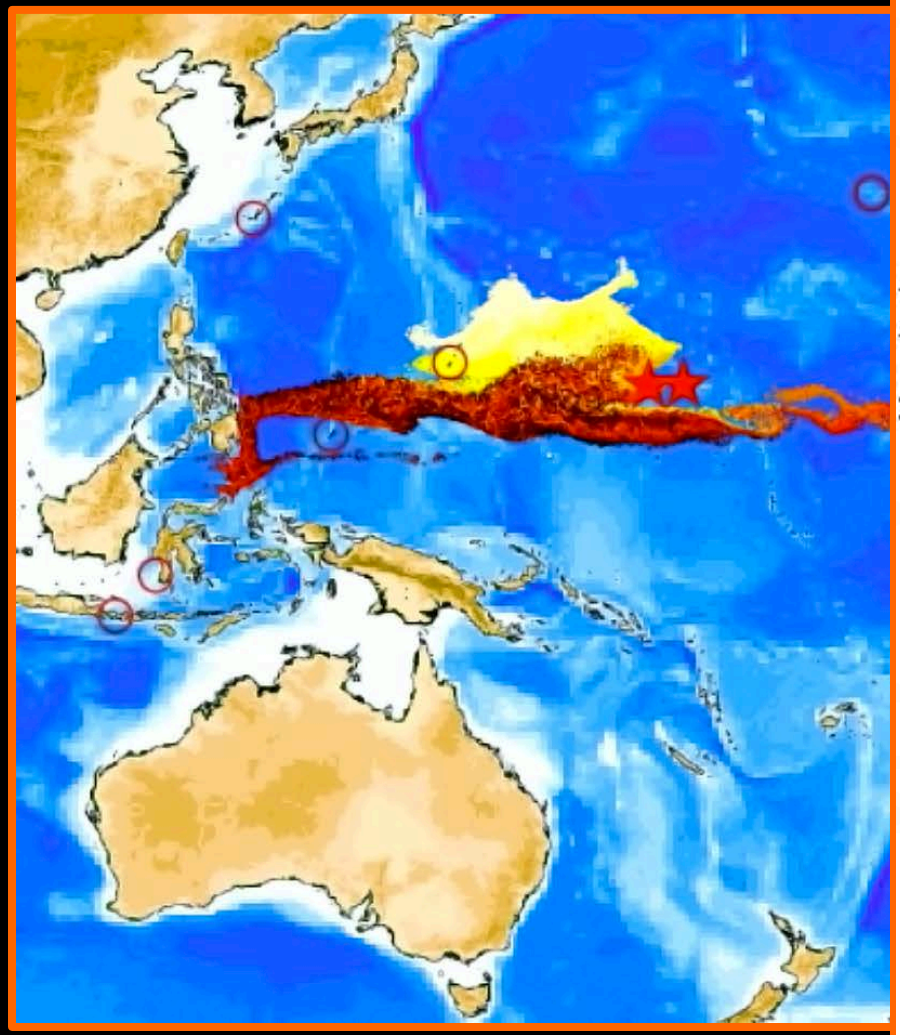
Surface Bomb Radioactivity Propagation

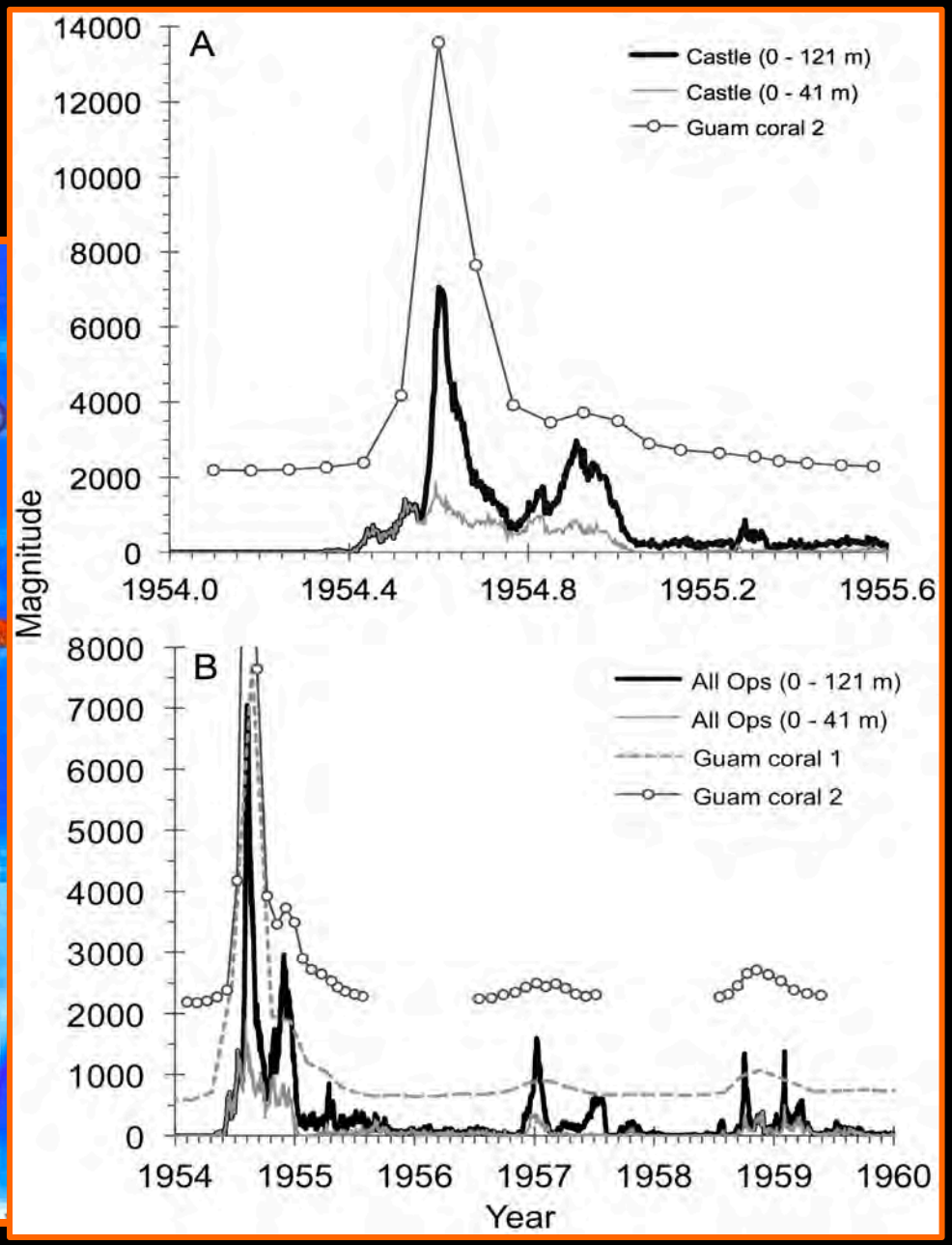
Fallout propagation modeling using 10 depth stratified layers
Each modeled event was >1 Mt and begins at the test date



Surface Bomb Radioactivity Propagation

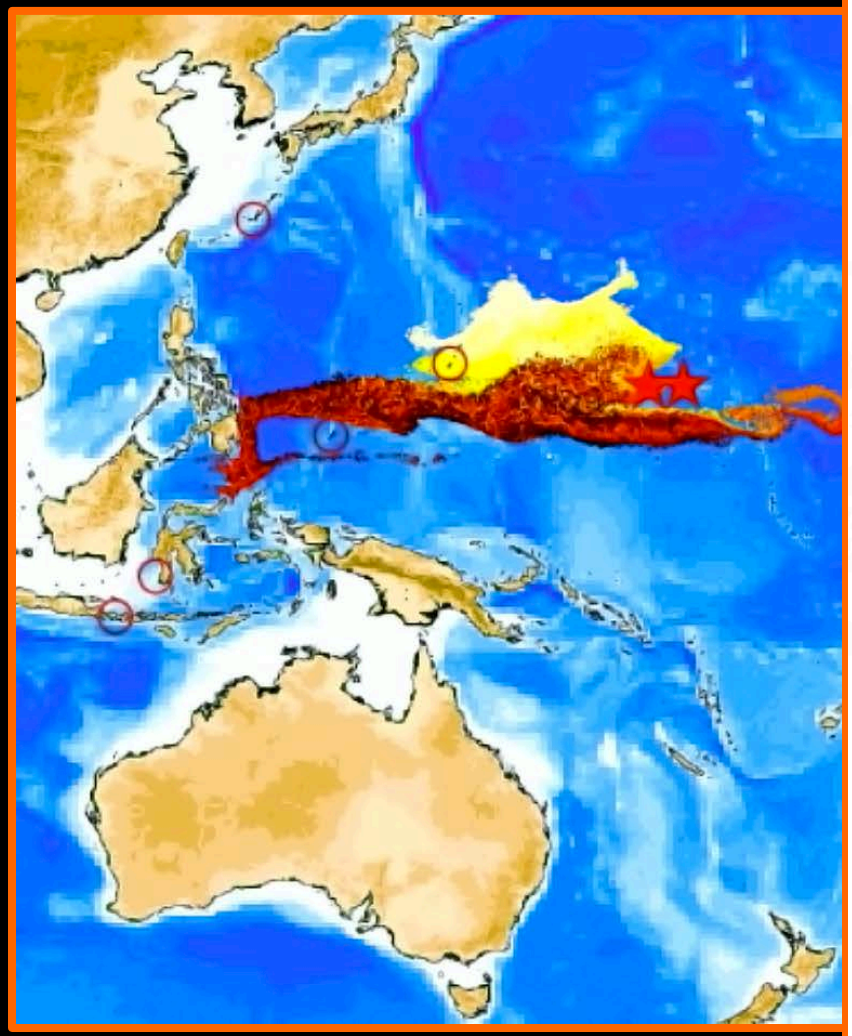
Guam coral ^{14}C record nearly coincident with modeling

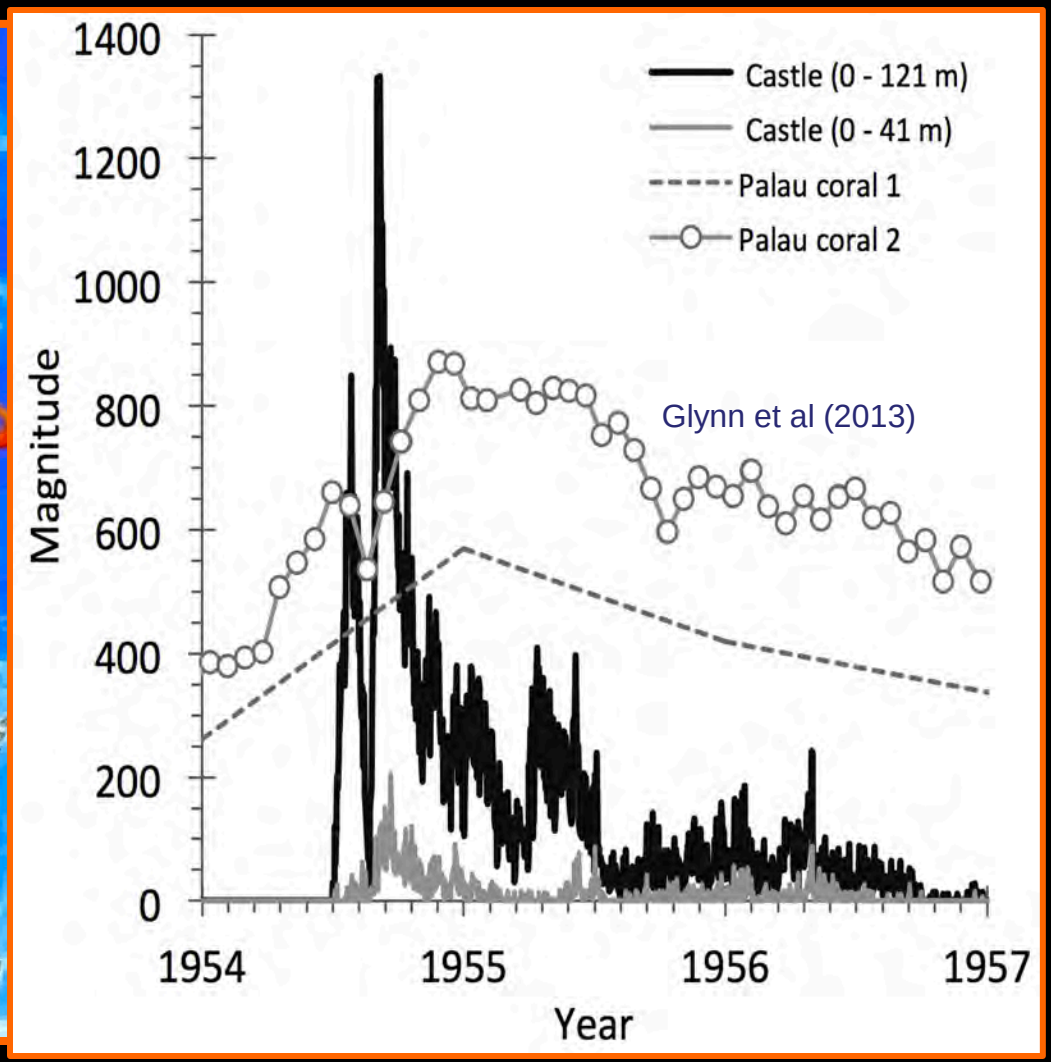




Surface Bomb Radioactivity Propagation

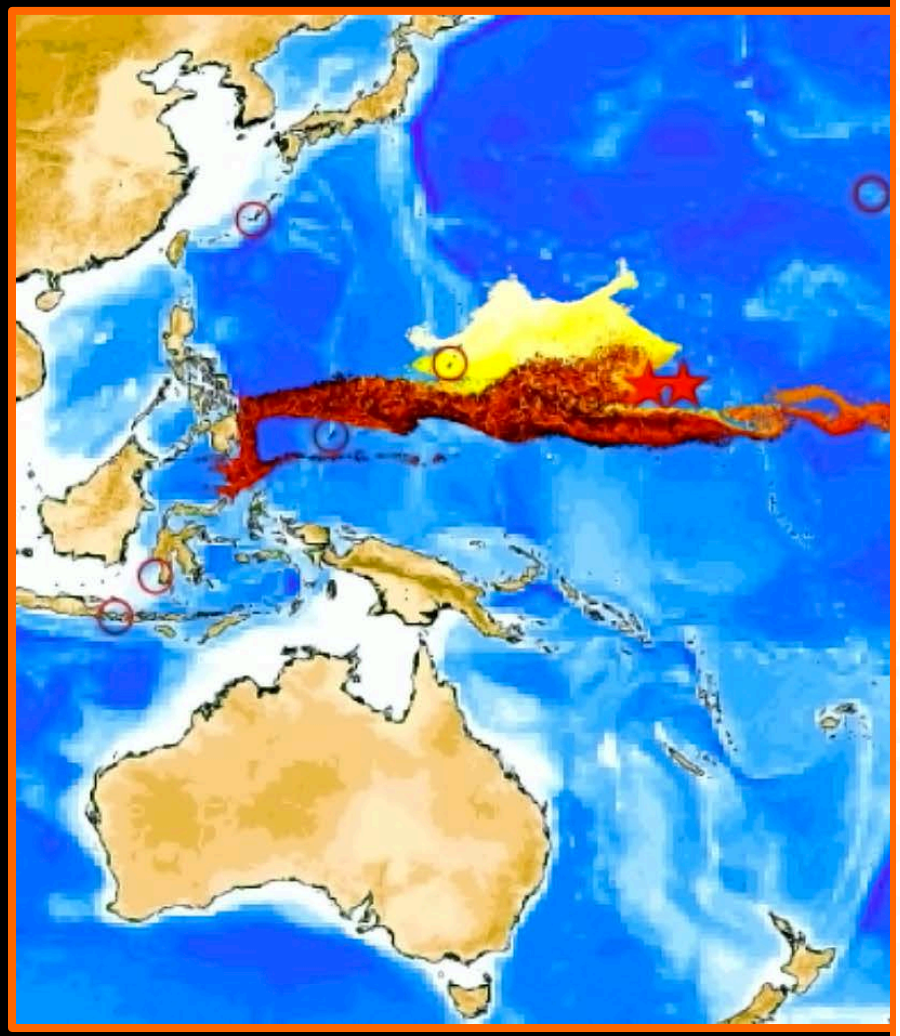
Palau coral ^{14}C record nearly coincident with minor offset and similar split peak (Castle Bravo and Union signals)

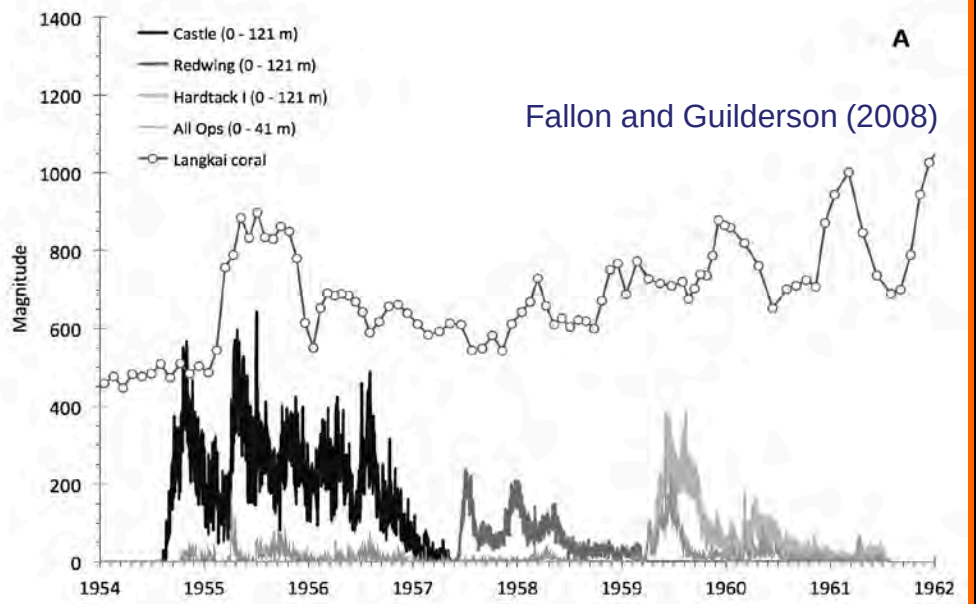




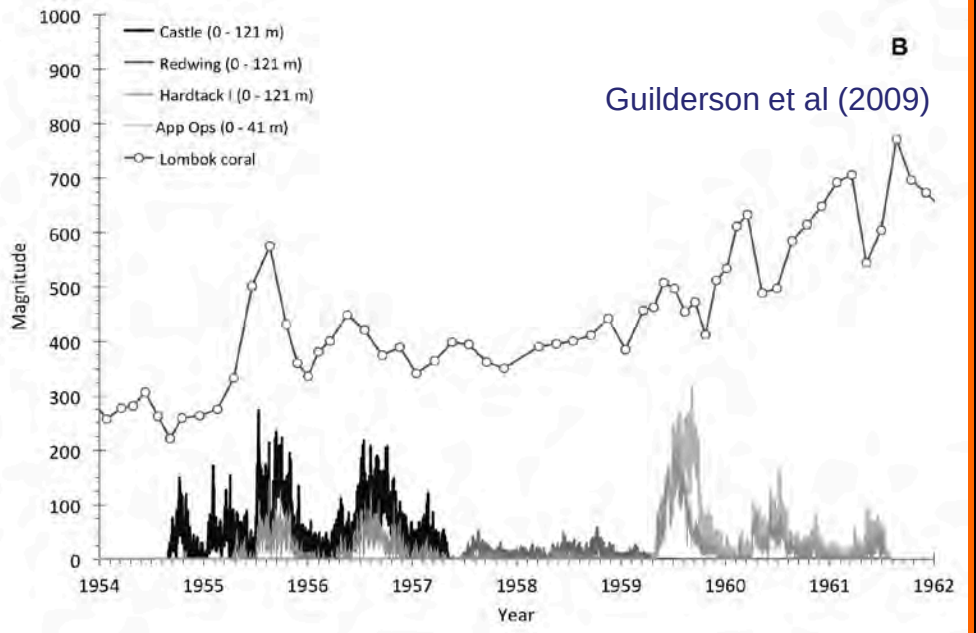
Surface Bomb Radioactivity Propagation

Indo-Pacific Throughflow complicated but confirms Castle





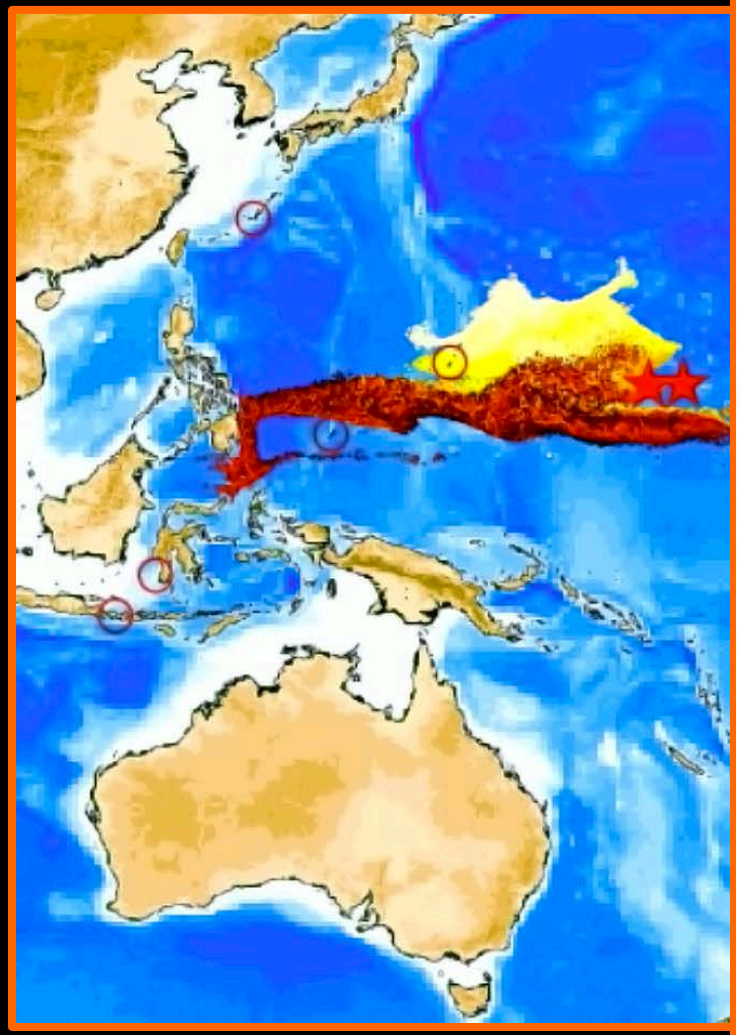
Fallon and Guilderson (2008)

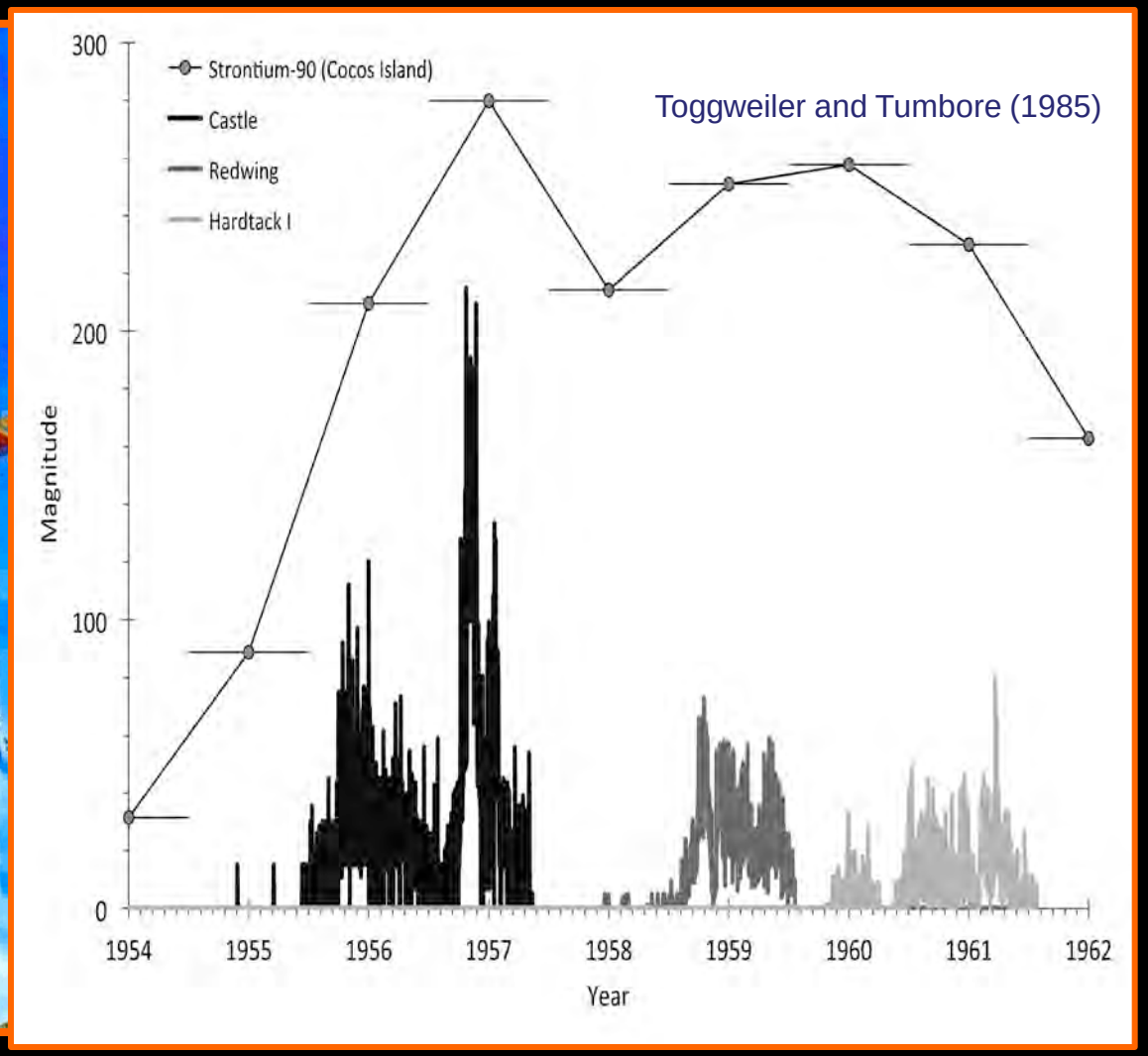


Guilderson et al (2009)

Surface Bomb Radioactivity Propagation

Bonus run – Confirmed hypothesis that Sr-90 signal at Cocos-Keeling Islands as fallout propagation from Pacific Proving Grounds





Mechanism – Incorporation of bomb ^{14}C to close-in fallout

Thermonuclear explosions produce an enormous burst of neutrons within the first few microseconds

Most neutrons are absorbed by atmospheric nitrogen = ^{14}C = $^{14}CO_2$

Source of ^{14}C created in atmosphere immediately surrounding fireball

Most ^{14}C entrained by superheated, toroidal cloud and advected into stratosphere

Some $^{14}CO_2$ incorporated by cooling substrates (vaporized/pulverized coral)
(Only bombs that made fireball contact with island and sea surfaces)
Subsequent dissolution at sea surface = Close-in fallout

Some $^{14}CO_2$ directly absorbed into cooling water vapor cloud
(Most surface blasts vaporized a massive volume of sea water)
Subsequent infusion to sea surface