Dating

courting courtship suit determine the age of an object

¹⁴C dating was developed by Willard Libby (1908-1980) in 1949

1960 noble prize in chemistry



Libby

¹⁴C halflife

Constancy in time

Constancy in space

Closed system

Equilibrium



modelling, dating, source partitioning

Libby's dating model

Radioactice decay

- IR(t) isotope ratio at time t
- IR_0 isotope ratio at time zero
- λ decay constant = ln 2 / $T_{1/2}$

Libby's dating model assumes

- during life object is in equilibrium with atmosphere
- after dead it is a closed system
- IR_0 constant in time and space
- $T_{1/2} = 5568 \text{ yrs} \ (=> \lambda = 8033 \text{ yr}^{-1})$

CRA conventional radiocarbon age

 $CRA = -\frac{1}{\lambda} \cdot \ln(F^{14}C)$



 $IR(t) = IR_0 \cdot e^{-\lambda t}$

Libby

¹⁴C half-life

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Summary of the remaining lecture

Libby

¹⁴C half-life

Constancy

Constancy

in space

Closed

system

Equilibrium

Summary,

in time

Libby's dating model is simply ingenious

- with small corrections it allows dating (archeology)
- deviations are often valuable to be investigated (ecology)

Corrections due to violations of the basic assumptions:

- during life object is in equilibrium with atmosphere
- after dead object is closed system
- IR_0 constant in time and space
- $T_{1/2} = 5568 \text{ yr}$









	Reasons are variation of	Libby
	• cosmic ray intensity	¹⁴ C half-life
	(=activity of the sun)	Constancy
	• Earth magnetic field	in time
	 CO₂ concentration in air 	Constancy
	WII	
		Closed
	CRA not meaningful except as ΔIR	system
		Equilibriun
00		Summary

An example where deviation from Libby's basic assumption lead to 14C application:



Number of sunspots reconstructed by different methods (Solanki et al., Nature 431 (2004) 1084)





Example: $F^{14}C = 0.9125 \pm 0.0026$ analysis with OxCal

- red: measurement
- Lila: calibration curve Grey: density
 - probability of age



Libby Constancy in time Constancy in space Closed Equilibrium **Summary**

Example: $F^{14}C = 0.9125 \pm 0.0026$ analysis with OxCal

red: measurement Lila: calibration curve Grey: density probability of age

another example $F^{14}C = 0.98 \pm 0.0025$



Constancy in space of the isotopic ratio IR_0 in time



Libby



example of "deviations which are valuable to be investigated"



 Δ^{14} C measurements of corn during the summer 2004, 2.8 ‰ ≈ 1 ppm fossil CO₂ Hsuch et al. 2007

Small handicap for dating, but large chances for carbon cycle applications Libby Constancy in time **Constancy** in space Closed system Equilibrium Summary



Solution for dating: several calibration curves



Note: OxCal, Calib, etc are programs to deduce ages with the help of calibration curves. But the calibration curves are produced by a team of scientists, e.g. Reimer et al., Radiocarbon 55 (2013) 1869

Libby

¹⁴C half-life

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Basic assumption: closed system



Basis of dating bones: no collagen enters the bone (but it can decay) It counts not only stability, but also immobility. Libby Constancy Constancy in space Closed system Summary

Basic assumption: equilibrium with athmosphere

Freshwater reservoir effect (lakes, rivers): **Dissolved carbonates (hardwater effect) Oxidation of old organic matter Glacier water containing old CO**₂ Effect can be several k yrs. It can vary within one lake or river, can have temperoral variability, vary between different species Due to exchange between carbonates and dissolved CO₂ also non-carbonat-assimilating aquatic plant are influenced. Land animals can be influenced over the food chain

Libby

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Global AR Values on a RGB Colour Scale

This takes a long time to load. Be patient..
 The dots are all 100km in radius. The map projection distorts their size at high latitudes
 Each color shade increment represents -16 units of AR

Libby

Constancy

Constancy

in space

Closed

Equilibrium

Summary



http://calib.org/marine/google/

Correction depends on ocean circulation → It depend on the time era

Dating land snails

The carbon in snail shells can originate from

- atmospheric CO₂,
- food,
- water, and
- carbonate rocks.

For some species the age anomaly is a few k yrs. For other species only a fraction of the samples show an age anomaly. Again other species show no age anomaly at all.



Caution: Freshwater reservoir effect, marine reservoir effect and land snails are examples ! Watch the carbon source !!! Libby

¹⁴C half-life

Constancy in time

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Summary

¹⁴C is (one of) the best dating tools for ages below 50 k yrs (not mentioned)

Inaccuracy has many sources:

- Precision of *IR* meas.
- Calibration curve
- Contamination (sampling, sample preparation)
- Problems of sample type (equilibrium)
- Association of sample and event



Libby

¹⁴C half-life

Constancy in time

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