ARCHMAT
Advanced Analytical Methods

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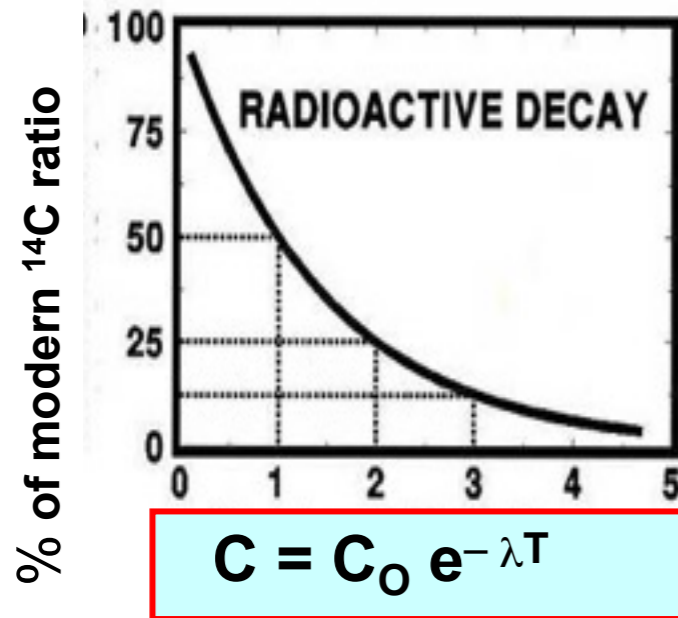**Cosmogenic Radionuclides**

Dating Techniques

Relative Techniques

- Seriation
- Patination
- Pollen Analysis
- Obsidian Hydration
- Cultural Affiliation
- Stratigraphy

- Dendro-Cronology
- Archeo-Magnetism

AAR

Absolute Techniques

Radioactive Decay
- Radio-Carbon
- Potassium-Argon
- Uranium Series

Ionising Radiation
- Luminescence
- ESR
- Fisson-track
- Cosmogenic

(1) Atmospheric production

% of modern ^{14}C ratio

RADIOACTIVE DECAY

$$C = C_O\, e^{-\lambda T}$$

T = Radiocarbon dating

(2) Surface production

^{10}Be million atom/g

$$C = P/\lambda\,(1 - e^{-\lambda T})$$

T = Exposure dating

high-energy primary galactic proton
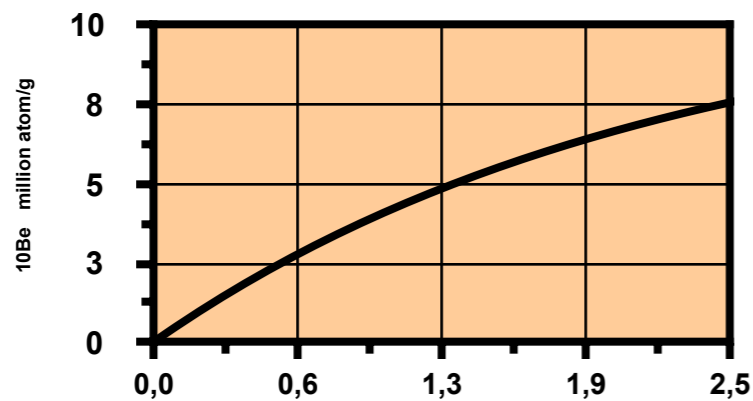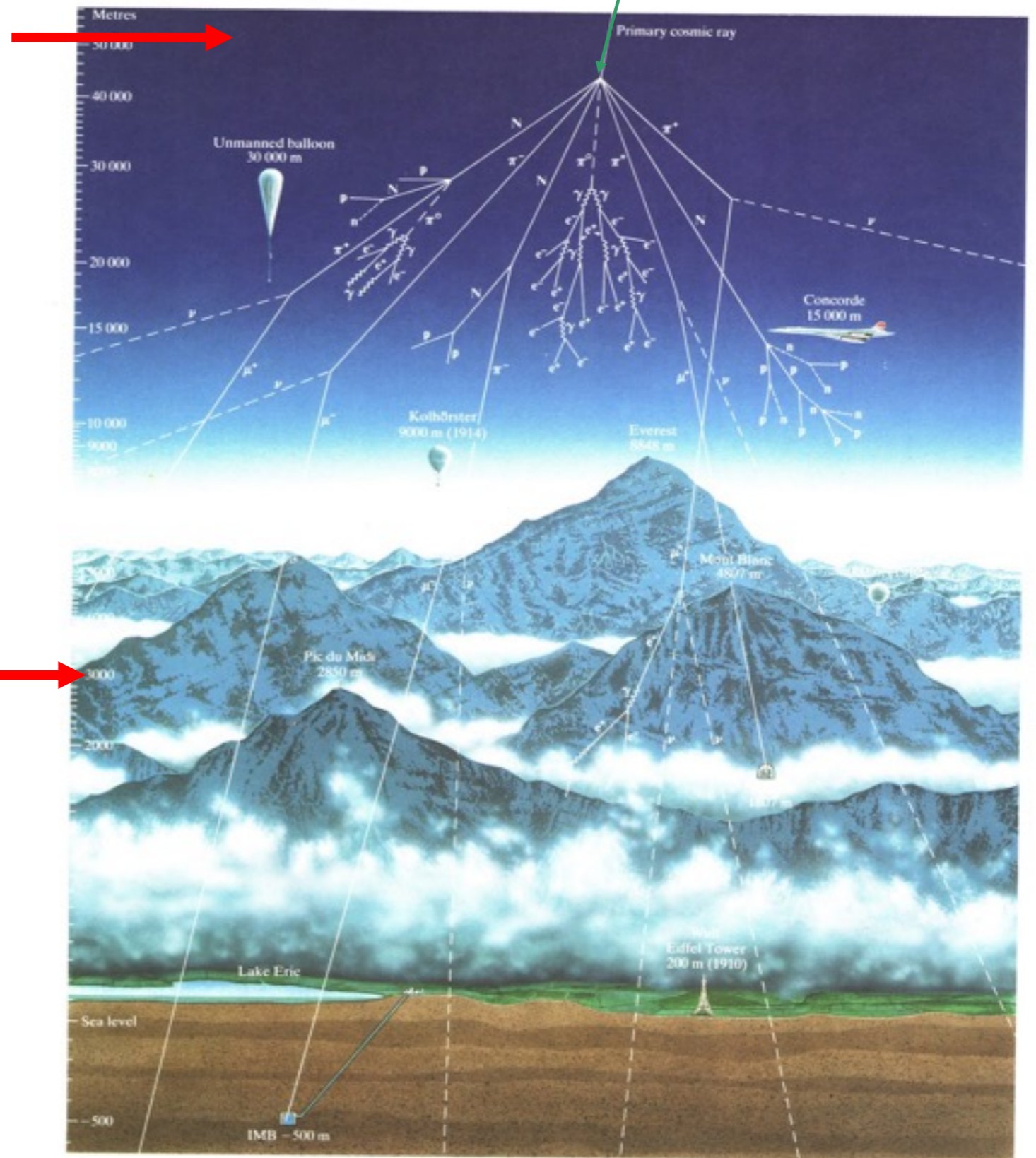
$^{10}Be,\quad ^{14}C,\quad ^{26}Al,\quad ^{36}Cl$

$$T_{1/2} \sim 5\ ka\ -\ 1.5\ Ma$$

Burial Dating Scenario

- Rock/sediment/clast/ artifact exposed to cosmic rays at surface of earth (ie initial dose)

- Sediment transported and deeply buried into cave (>10 m)

- Production of ^{10}Be and ^{26}Al ceases due to complete shielding

- Radionuclide inventories decay at different rates

- Measure concentration ratio, R

- Compare measured R (t_B) to initial R (t_0)

- Correct for partial shielding if shallow burial

Burial dating

The concentration of cosmogenic nuclides in buried sediment is calculated from radioactive decay of the inheritance plus post-burial production.

$$C_{26} = C_{26}(t_0)\, e^{-\lambda_{26} t_B} + P_{26}\,(d)\,(1 - e^{-\lambda_{26} t_B})/\lambda_{26}$$

$$C_{10} = C_{10}(t_0)\, e^{-\lambda_{10} t_B} + P_{10}\,(d)\,(1 - e^{-\lambda_{10} t_B})/\lambda_{10}$$

ignoring post-burial production and assuming an inherited ratio

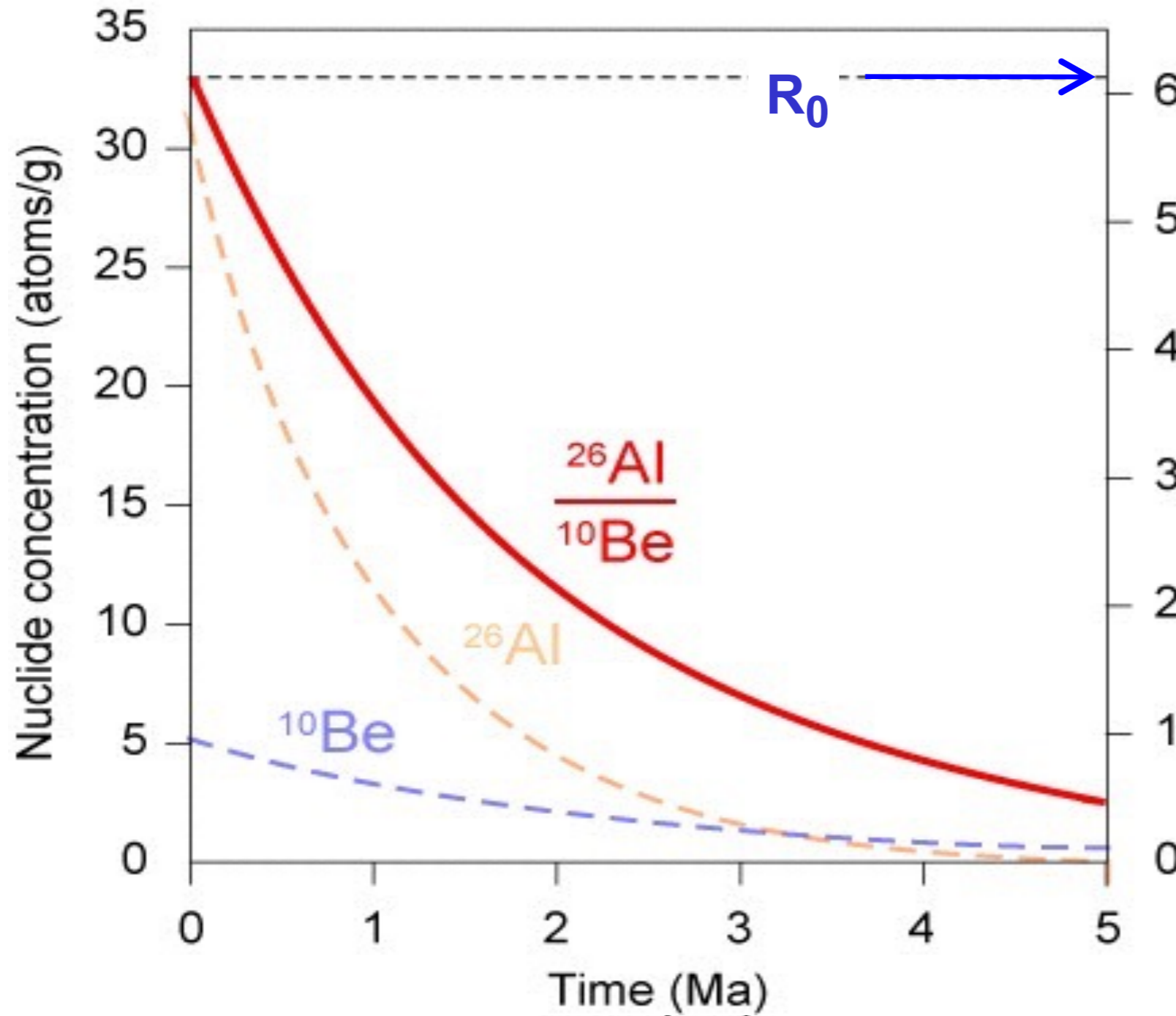$$C_{26}/C_{10} = R = R_{inh}(t_0)\, e^{-\lambda_{eff}\, t_B}$$

where

$$\lambda_{eff} = (\lambda_{26} - \lambda_{10})$$

Deeply buried sediments → P(d) =0

$$C_{10} = C_{10}(t_0) \exp^{-\lambda_{10}t_B} \qquad C_{26} = C_{26}(t_0) \exp^{-\lambda_{26}t_B}$$

$$R = C(^{26}Al) / C(^{10}Be) = R_0 \, (^{26}Al/^{10}Be) \exp^{-(\lambda_{26} - \lambda_{10})\, t_B}$$

R_T = AMS measurement

R_0 = initial ratio ~6

t_B = burial time

$^{10}Be \; (t_{1/2} = 1.38 \pm 0.02 \; Ma)$

$^{26}Al \; (t_{1/2} = 0.70 \pm 0.03 \; Ma)$

Minimal post-burial production

Continual exposure during partial burial

Peking Man
(*H. erectus*)

Cosmogenic dating has determined the age of Peking Man to around 750,000 years old.

Shen et al Nature 2009

Homo antecessor

Atapuerca, Spain
Oldest dated hominins in Europe
(1.29 +/- 0.09 Ma).

Carbonell et al. Nature 2008