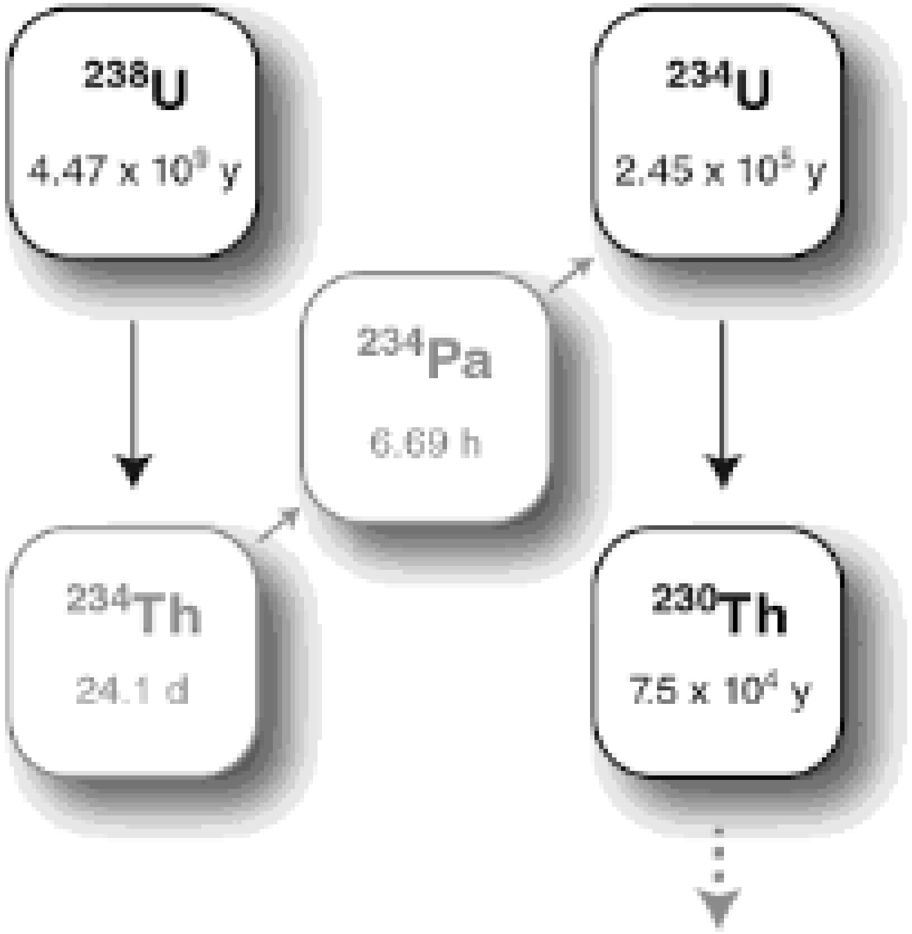
Uranium –Thorium Dating

U-series uses uranium and thorium decay-series applied to carbonates to date the time of element fractionation processes that have geological significance, e.g. the fractionation that occurs as a consequence of carbonate precipitation.

Principles of the Method

Uranium-238 decay in a series of stages to various daughter elements with differing half lives. One of these are useful for dating as well, throium-230

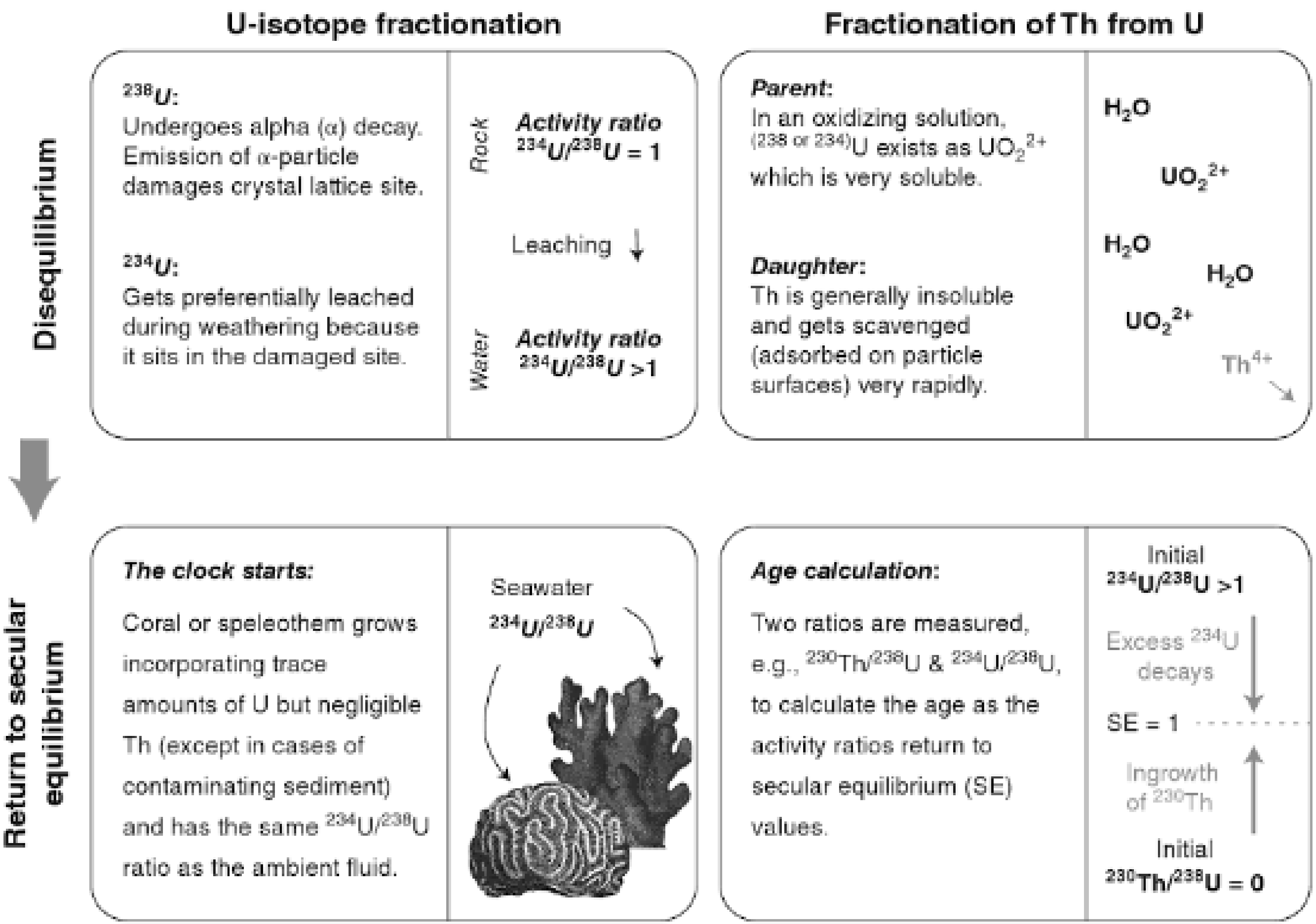


- A key factor in the method is that uranium is soluble in water while the daughter products are non-soluble.
  This means that uranium is present in water which seeps into limestone caves but it's non-soluble daughter products are not. As this uranium becomes part of the travertine of the caves this is the zero event.
  Daughter isotopes present in the sample increase through time and the ratio is measured to provide an age estimate. Most commonly the ratio of uranium-238 to thorium-230 is measured.

Uranium-Thorium clockwork

Uranium-Thorium dating is an absolute dating technique which uses the properties of the radio-active half-life of the two alpha emitters ^{238}U and ^{230}Th. The half-life of ^{238}U is $T_{1/2}$=4,470,000,000 y. The half-life of ^{230}Th is comparably short, only $T_{1/2}$=75,380 y. When the amounts of uranium and thorium are compared an accurate estimation of the age of an object can be obtained. This method can only be applied to objects which initially had no ^{230}Th content.

$$\frac{^{230}Th}{^{238}U} = \left(1 - e^{-\lambda_{230} \cdot t}\right) + \frac{\lambda_{230}}{\lambda_{230} - \lambda_{234}} \cdot \left(\frac{^{234}U}{^{238}U} - 1\right) \cdot \left(1 - e^{-(\lambda_{230} - \lambda_{234}) \cdot t}\right)$$



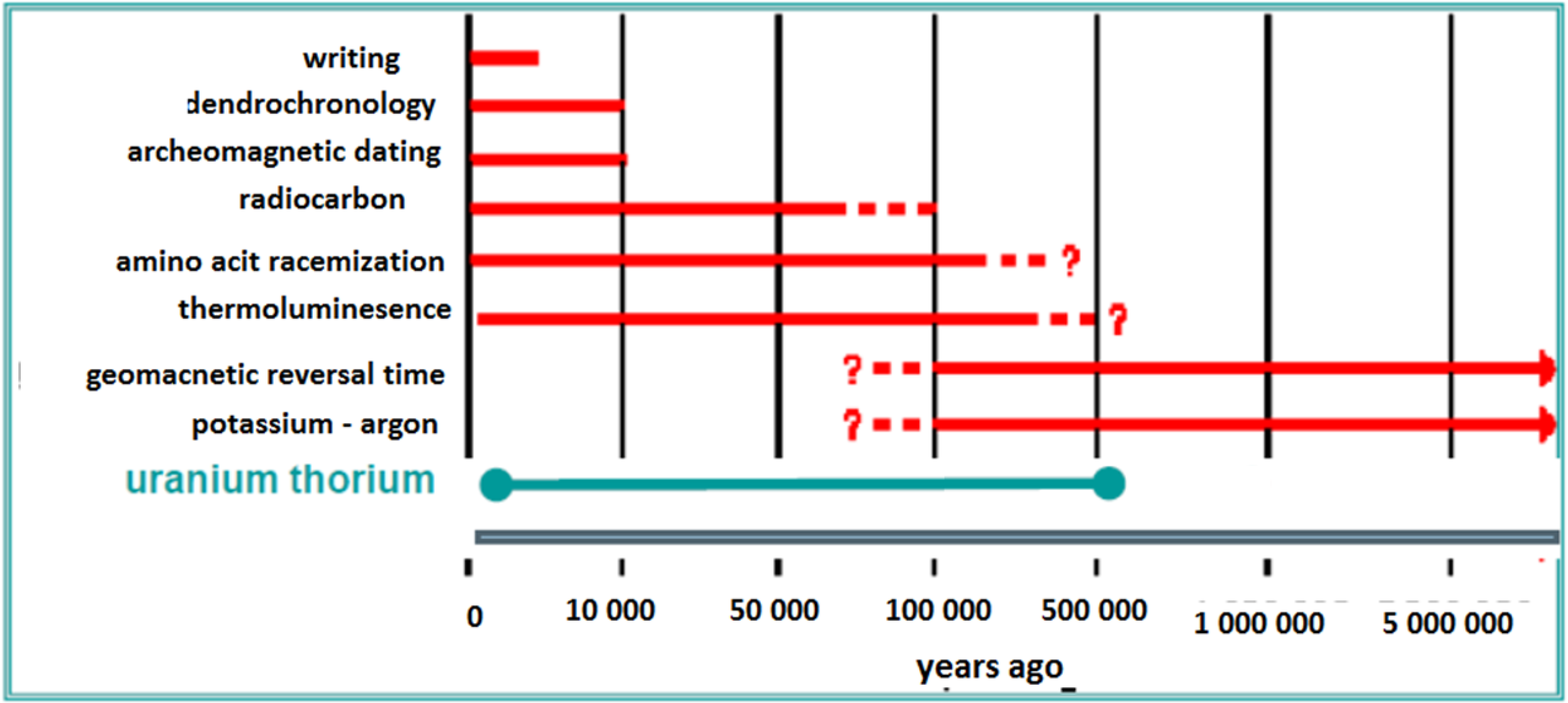
U-isotope fractionation
Fractionation of Th from U
Disequilibrium
238U:
Undergoes alpha (α) decay. Emission of α-particle damages crystal lattice site.
234U:
Gets preferentially leached during weathering because it sits in the damaged site.
Rock
Activity ratio 234U/238U = 1
Leaching
Water
Activity ratio 234U/238U >1
Parent:
In an oxidizing solution, (238 or 234)U exists as UO2 2+ which is very soluble.
Daughter:
Th is generally insoluble and gets scavenged (adsorbed on particle surfaces) very rapidly.
H2O
UO2 2+
H2O
H2O
UO2 2+
Th4+
Return to secular equilibrium
The clock starts:
Coral or speleothem grows incorporating trace amounts of U but negligible Th (except in cases of contaminating sediment) and has the same 234U/238U ratio as the ambient fluid.
Seawater 234U/238U
Age calculation:
Two ratios are measured, e.g., 230Th/238U & 234U/238U, to calculate the age as the activity ratios return to secular equilibrium (SE) values.
Initial 234U/238U >1
Excess 234U decays
SE = 1
Ingrowth of 230Th
Initial 230Th/238U = 0

Age range:

From few years to 350,000- 500,000 years

(for ^{234}U-^{230}Th)

While radiocarbon is limited about with 50000 years and K-Ar is limited with volcanic material and also used to be limited to samples of 100000 year of age,


writing
dendrochronology
archeomagnetic dating
radiocarbon
amino acit racemization
thermoluminesence
geomacnetic reversal time
potassium - argon
uranium thorium
0
10 000
50 000
100 000
500 000
1 000 000
5 000 000
years ago

- **Can be used to date:**

Terrestrial carbonates (speleothems, tufa deposits, lake sediments);

Marine carbonates (coral, shells); Human and animal bones, teeth and eggshell;

Groundwater (as a tracer, rather than dating method *per se*)

- **U/Th dating is great for:**
- **Dating clean carbonates (without detrital sources of thorium) which are densely cemented (reducing opportunity for open-systems behaviour during selective or partial dissolution)**
- **U/Th dating is ok for:**
- **Dating terrestrial bone, teeth and shell material (needing models for U uptake)**
- **Dating fresh and salt-water shells (problems with uranium exchange post-deposition, not a closed system)**

World’s Oldest Art? Uranium-thorium Dating Used on Spanish Cave Paintings

Jun 15th, 2012 · 0 Comment

Scientists tested the Spanish cave paintings, that were first discovered in the 1870's and found that one is at least 40,800 years old, which is about 15,000 years older than they previously thought. If they are this old, it makes the Spanish cave paintings older than the famous French cave paintings by thousands of years.

Scientists dated the Spanish cave paintings by the Neanderthals by measuring the decay of uranium atoms, instead of traditional carbon-dating. They tested the coating of these paintings in 11 different Spanish caves.

The Spanish paintings had built a crust of calcium carbonate on them over time. According to the Guardian, The crust held radioactive uranium, the element that decays to thorium. Measurements of the buildup of thorium could reveal how long ago those crusts formed and, since they were on top of the paintings, indicate a minimum age for the drawings.

Uranium-thorium dating has been in use since the 1960s but required hundreds of grams of calcium carbonate. Zilhão and Pike's team were able to use only a few tens of milligrams, with their new method.