Physics: Time and Archaeology

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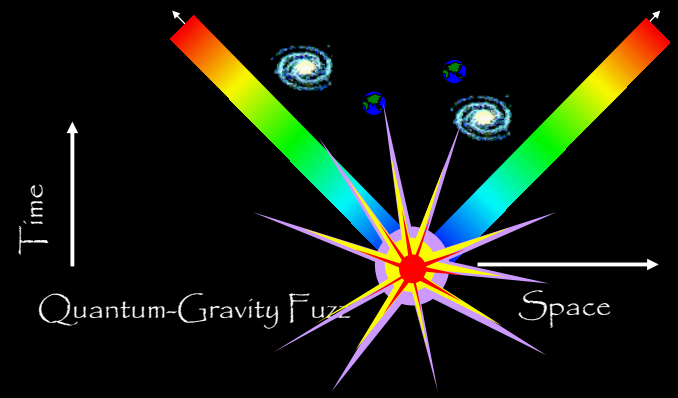
Part 1

Deep time – The age of the Earth

Origin

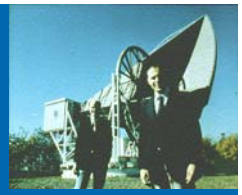
The Big Bang
Building the elements

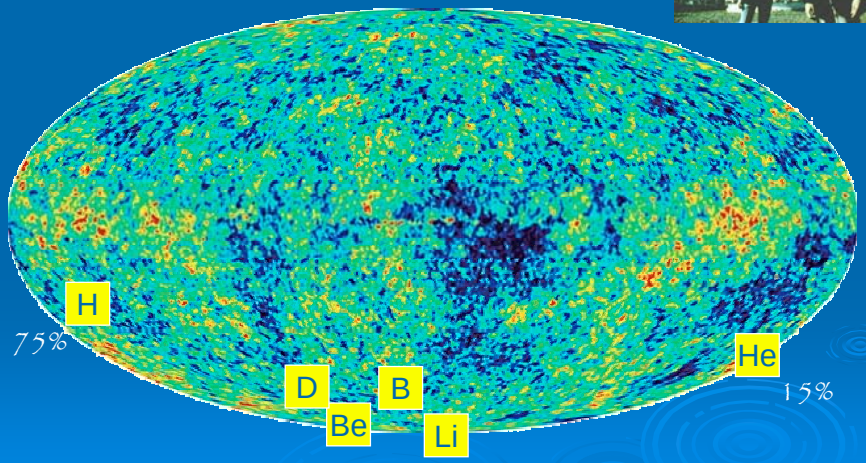
In the beginning: The Big Bang



13.7 Billion Years ago

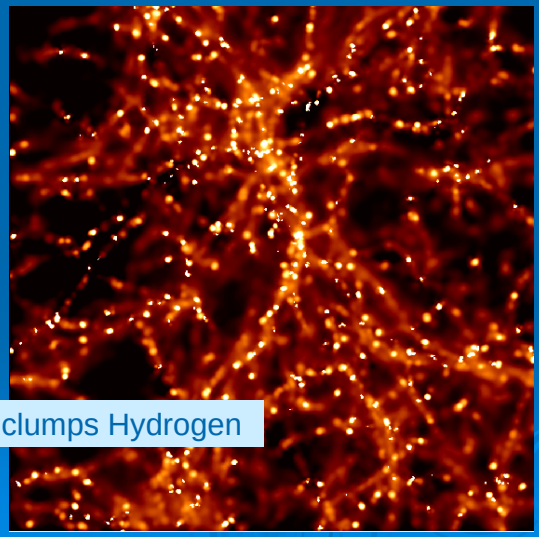
Big Bang All-Sky Afterglow





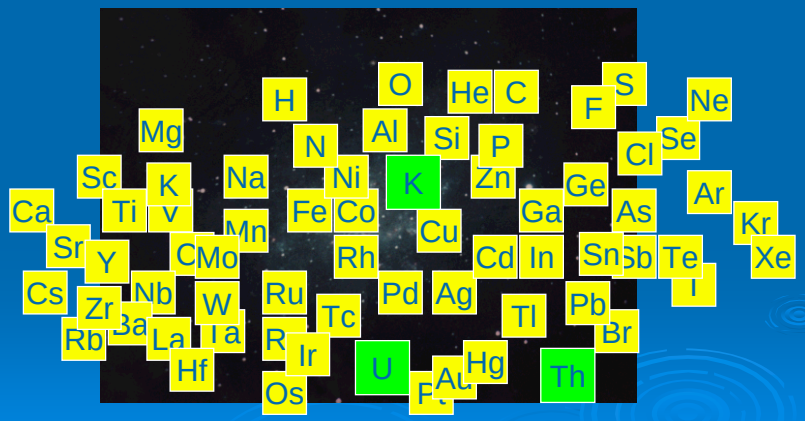
Wilkinson Microwave Anisotropy Probe

The First Stars

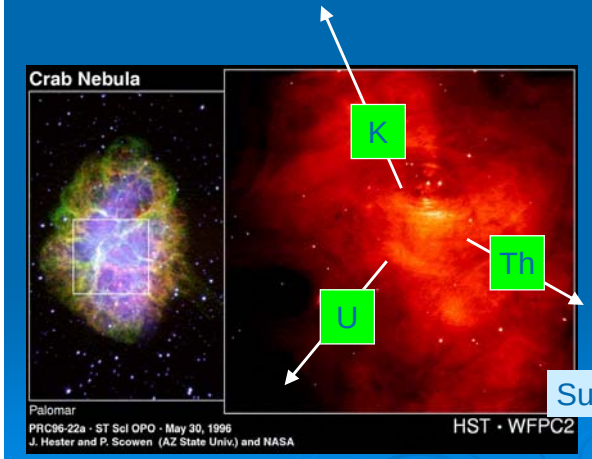


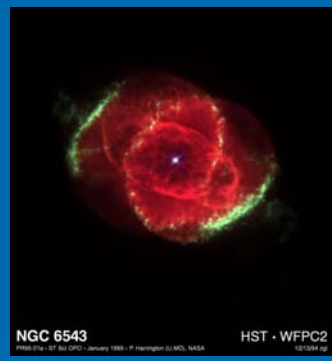
Gravity clumps Hydrogen

Nucleosynthesis Builds Elements



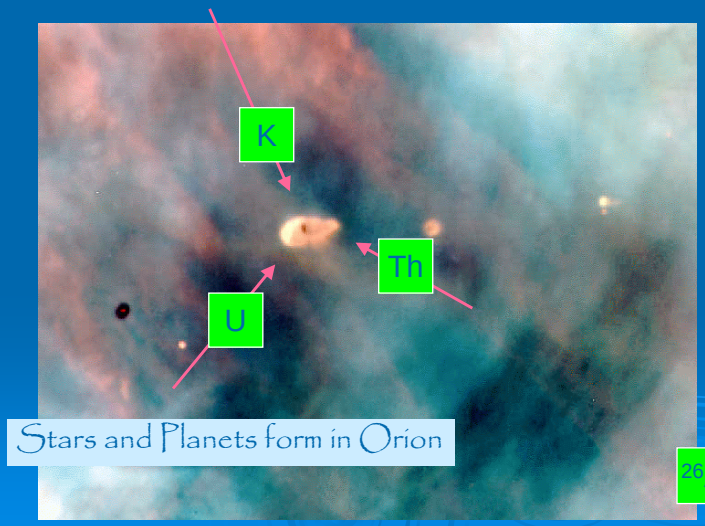
Star Supernovae Seed Interstellar Medium



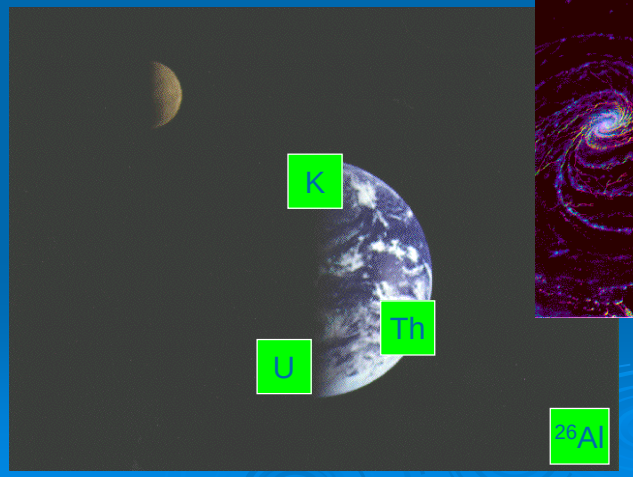


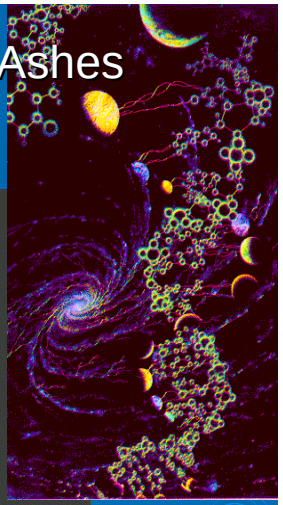
Supernova remnants

Stellar Ashes Build New Stars & Planets



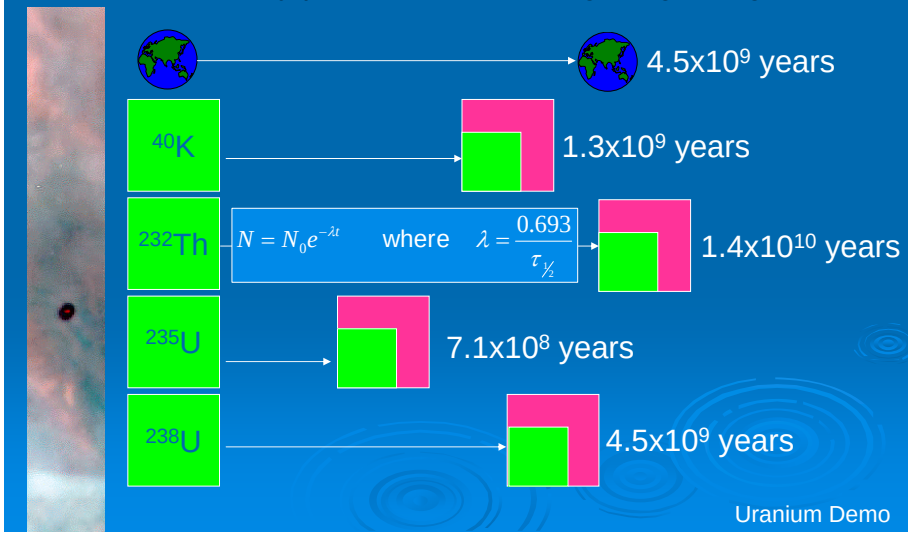
Earth Built From Stellar Ashes





Radioactive elements decay (slowly)

- Radioactivity provides dates over geological ages



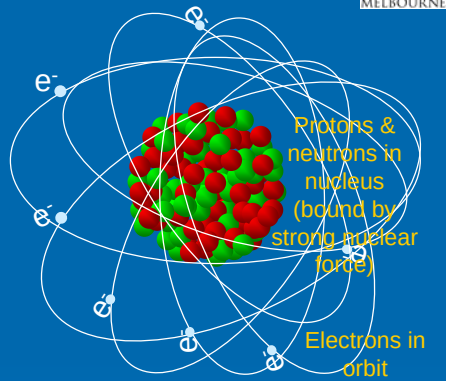
Uranium Demo

Isotopes and ionisation

Chemical symbol (defines number of protons, 19 in this case)

^{40}K

Number of nucleons (protons + neutrons)



Data:

- Of all the potassium (K) atoms in the Earth:
  - 93.1% are ^{39}K (stable)
  - 0.01% are ^{40}K (unstable, half life 1.3 billion years)
  - 6.9% are ^{41}K (stable)

$$^{40}K \rightarrow {}^{40}Ar + e^+ + \nu + energy$$

Not to scale: Nucleus is dust mote in a cathedral

The Potassium-Argon clock

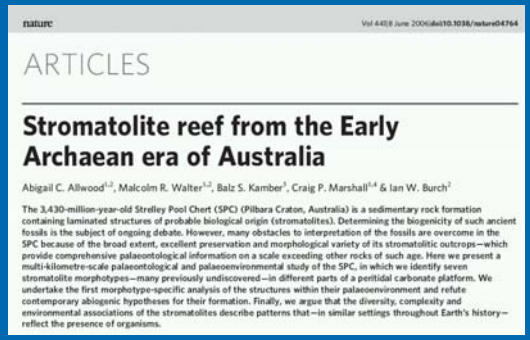
1.3 Billion Year half-life

$^{40}K \rightarrow {}^{40}Ar + e^{+} + \upsilon$

Argon detector

Useful for 4.3 billion years (the age of the Earth) to about 100,000 years before the present.

Relics of ancient life



nature Vol 441|8 June 2006|doi:10.1038/nature04764

ARTICLES

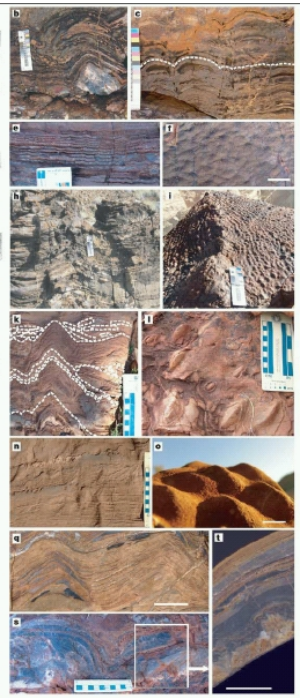
Stromatolite reef from the Early Archaean era of Australia

Abigail C. Allwood[1,2], Malcolm R. Walter[1,2], Balz S. Kamber[3], Craig P. Marshall[3,4] & Ian W. Burch[2]

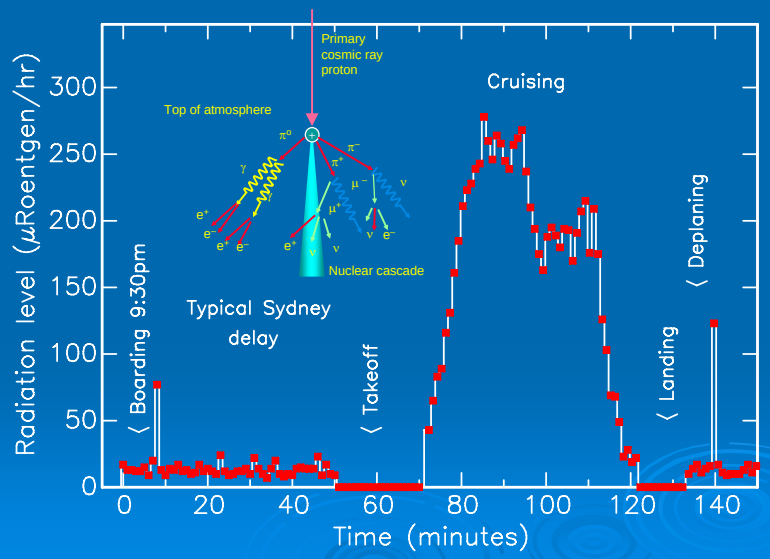
The 3,430-million-year-old Strelley Pool Chert (SPC) (Pilbara Craton, Australia) is a sedimentary rock formation containing laminated structures of probable biological origin (stromatolites). Determining the biogenicity of such ancient fossils is the subject of ongoing debate. However, many obstacles to interpretation of the fossils are overcome in the SPC because of the broad extent, excellent preservation and morphological variety of its stromatolitic outcrops—which provide comprehensive palaeontological information on a scale exceeding other rocks of such age. Here we present a multi-kilometre-scale palaeontological and palaeoenvironmental study of the SPC, in which we identify seven stromatolite morphotypes—many previously undiscovered—in different parts of a peritidal carbonate platform. We undertake the first morphotype-specific analysis of the structures within their palaeoenvironment and refute contemporary abiogenic hypotheses for their formation. Finally, we argue that the diversity, complexity and environmental associations of the stromatolites describe patterns that—in similar settings throughout Earth's history—reflect the presence of organisms.

3,430 million years old!

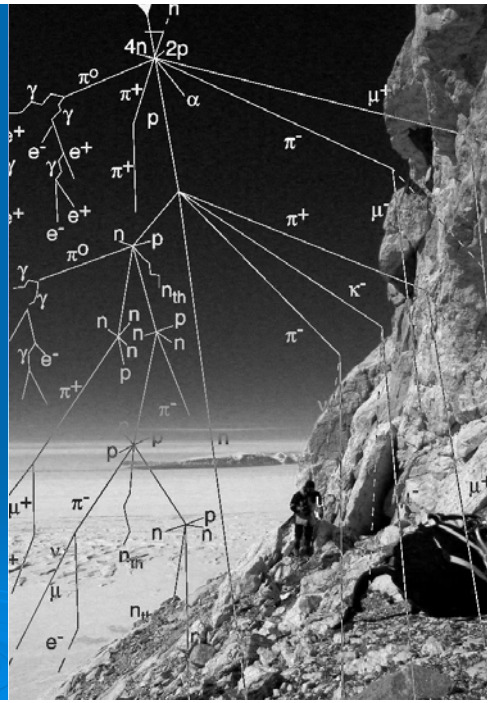
(76% age of Earth)



Cosmic Rays: High speed protons from outside the galaxy



Vast distances, high particle energies, multiple reactions leading to the production of ^{10}Be, ^{26}Al and a suite of other unstable and stable isotopes in the crust.



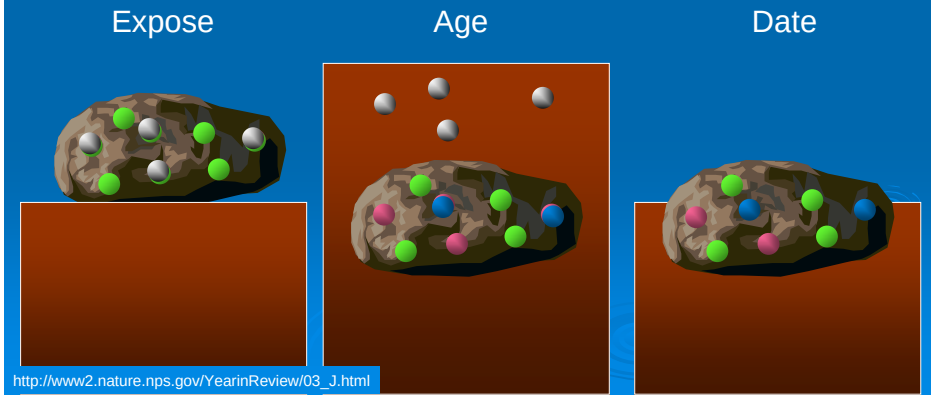
Source: D.X. Belton, CSIRO

Cosmogenic Isotopes

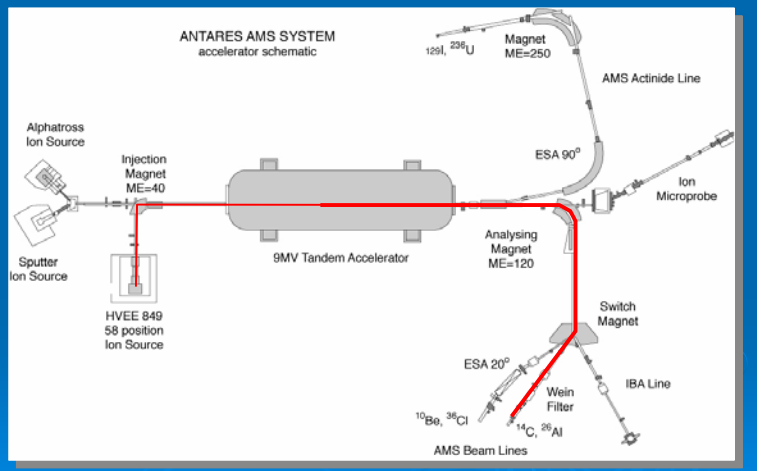
Element	Mass	half-life (years)	typical application
helium	3	- stable -	exposure dating of olivine-bearing rocks
beryllium	10	1.51 million	exposure dating of quartz-bearing rocks, sediment, dating of ice cores, measurement of erosion rates
carbon	14	5,730	dating of organic matter, water
neon	21	- stable -	dating of very stable, long-exposed surfaces, including meteorites
aluminium	26	720,000	exposure dating of rocks, sediment
chlorine	36	308,000	exposure dating of rocks, groundwater tracer
calcium	41	103,000	exposure dating of carbonate rocks
iodine	129	15.7 million	groundwater tracer

Cosmogenic burial dating

- Aluminum-26
  - (0.73 million years)
  - Neutron spallation on Si in silica
- Beryllium-10
  - 1.6 million years
  - Neutron and muon spallation on Oxygen
- Ratio $^{26}Al/^{10}Be$ decreases exponentially with time as sand and gravel age

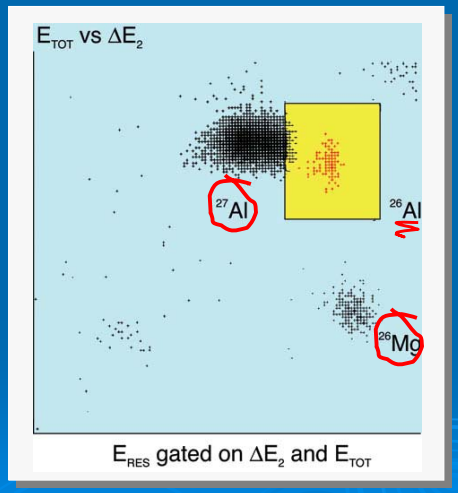


http://www2.nature.nps.gov/YearinReview/03_J.html

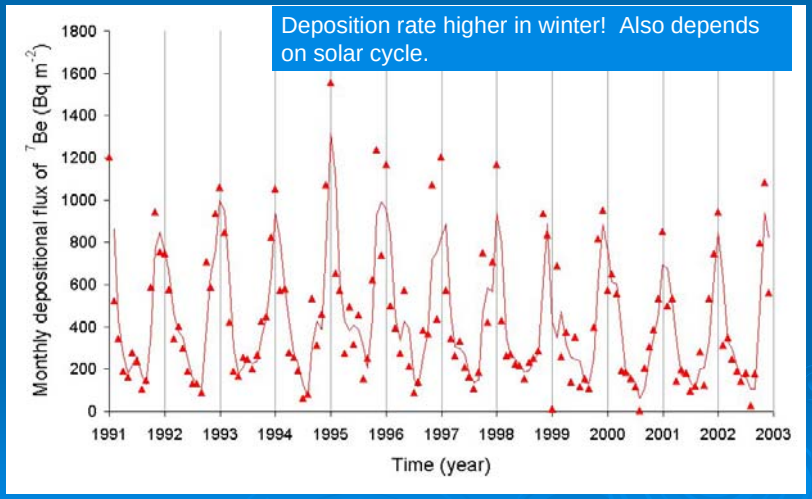


Accelerator mass spectrometry provides the answer

Source: D.X. Belton, CSIRO

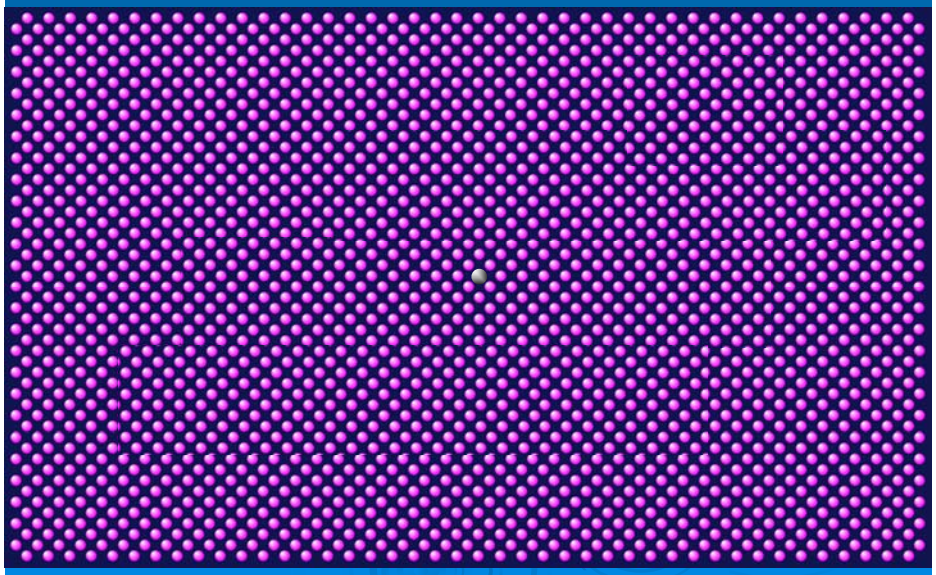


Need to Calibrate!



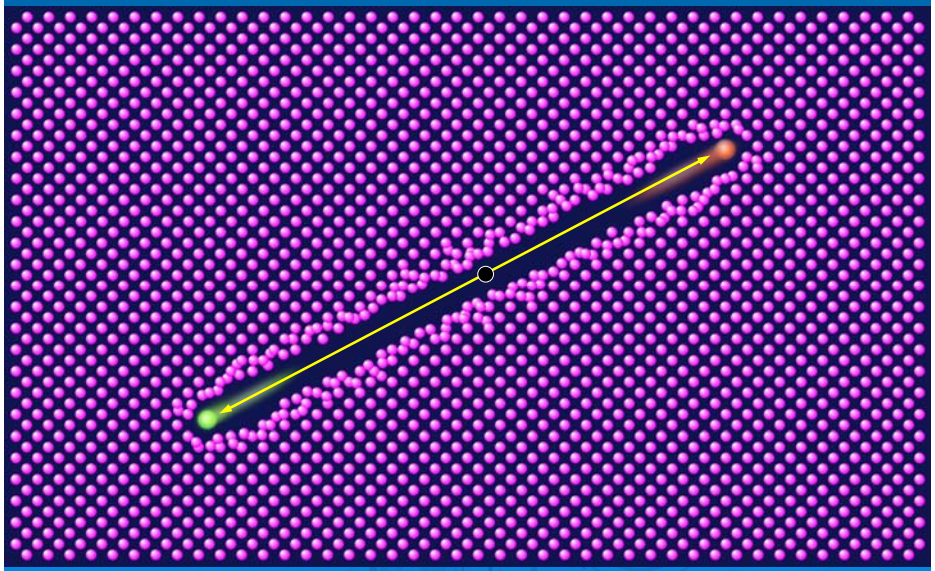
http://en.wikipedia.org/wiki/Image:Be7fromcosmicrays.jpg

Fission Tracks



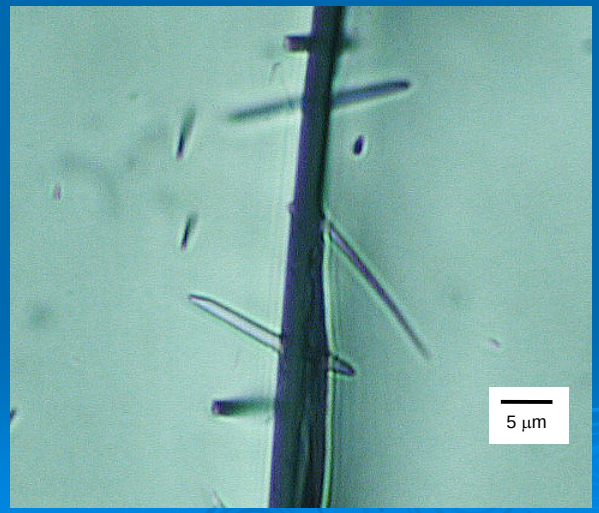
Fabian Kohlman, University of Melbourne, Earth Sciences

Fission Tracks



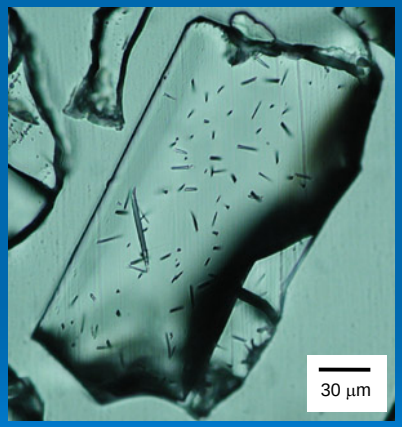
Fabian Kohlman, University of Melbourne, Earth Sciences

An etched fission track in apatite - ca. 16 μm



Source: D.X. Belton, CSIRO

Apatite fission track analysis

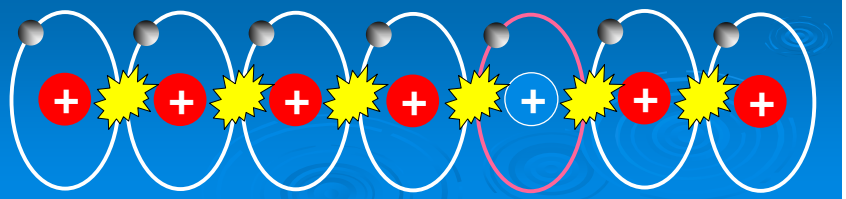


Source: D.X. Belton, CSIRO

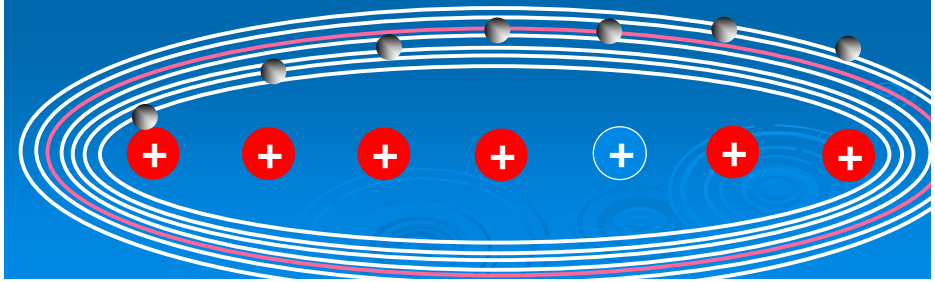
Part 2

Human time – The colonisation of Australia

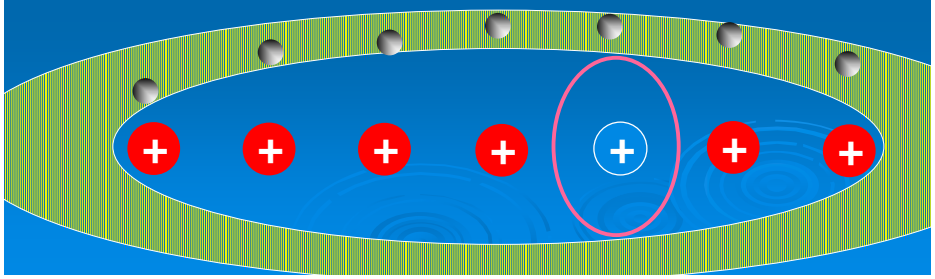
Building a Material



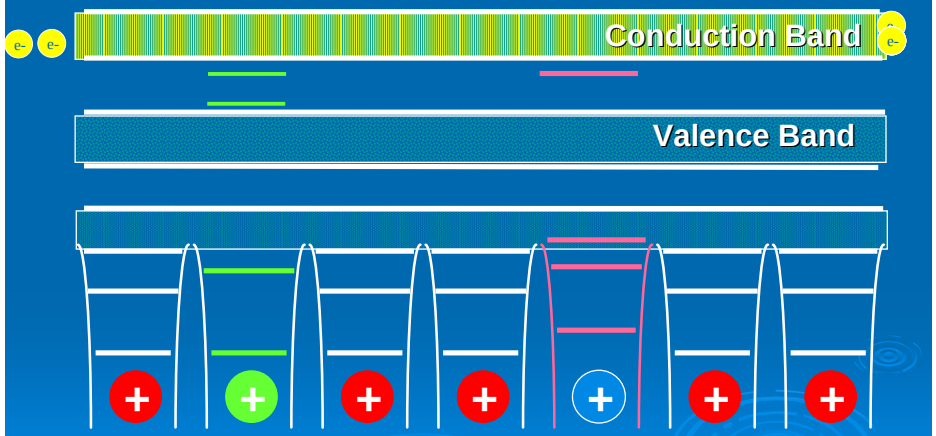
Building a Material



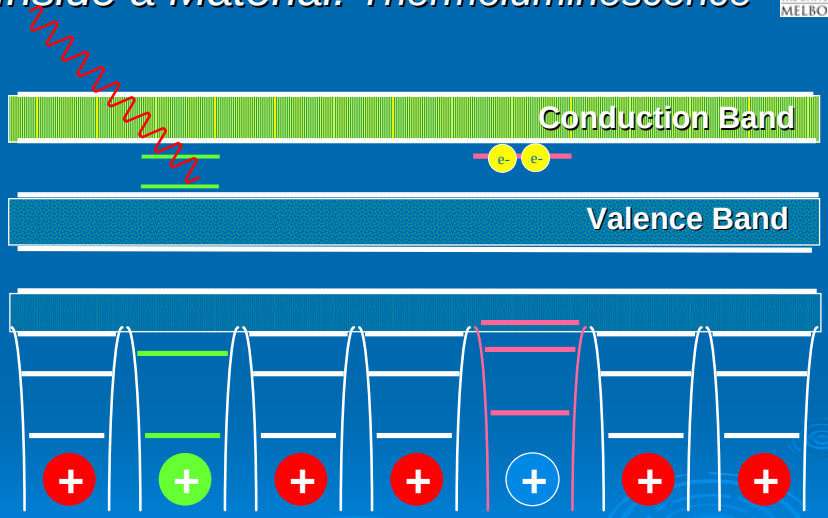
Building a Material



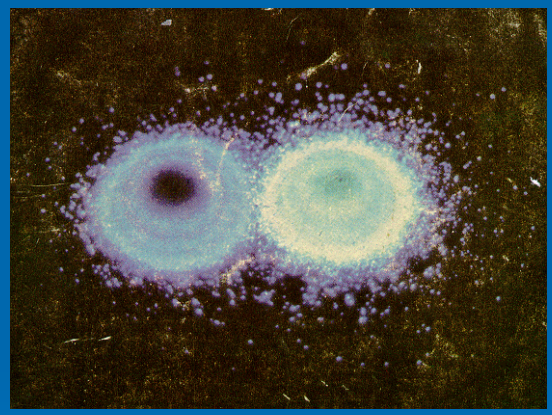
Inside a Material



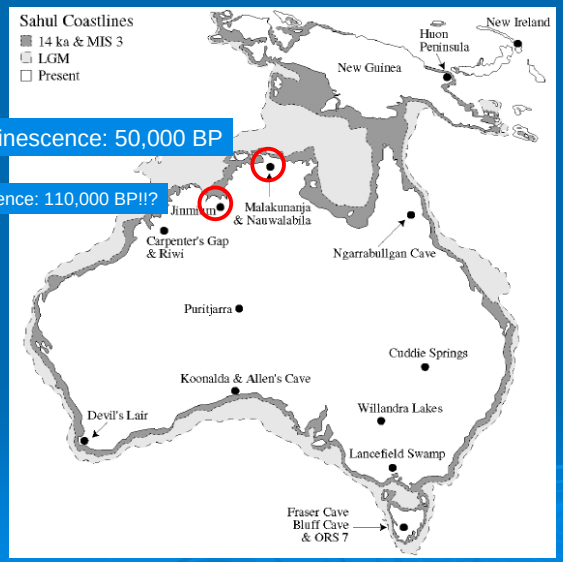
Inside a Material: Thermoluminescence



TV tube and phosphor demo



Light emitted from two piles of natural CaF_2 which have been γ irradiated and placed on a heated surface at about 200°C.

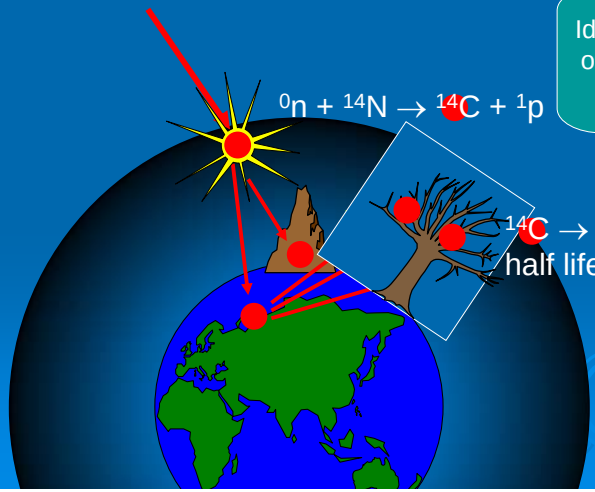


Thermoluminescence: 50,000 BP

Thermoluminescence: 110,000 BP!!?

RADIOCARBON, Vol 44, Nr 2, 2002, p 455–472

Radiocarbon ^{14}C



Ideal for dating dead organic matter from Humans

Radiocarbon ^{14}C

- 7.5 kg of ^{14}C produced annually
- Annual artificial CO_2 production 5,000,000,000,000,000 kg
- Total ^{14}C in atmosphere:

Isotope	Protons	Neutrons	Proportion	Half life
^{12}C	6	6	99%	stable
^{13}C	6	7	1%	
^{14}C	6	8	0.0000000001%	5568 years

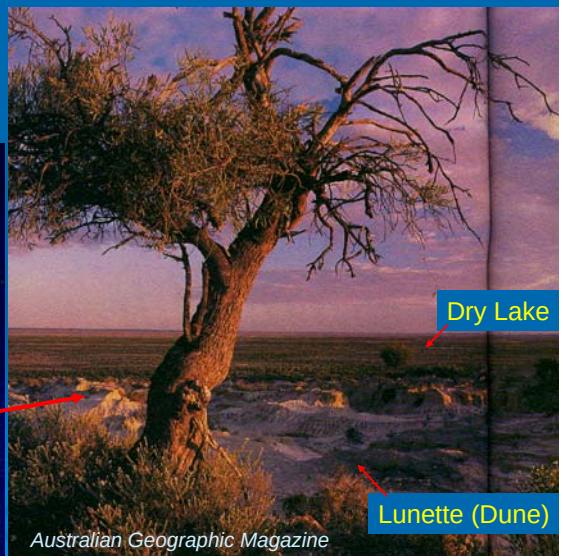
^{14}C production not constant!

Good back to 8000 BC http://www.sonic.net/bristlecone/dendro.html

Lake Mungo

^{14}C dates

- Human remains:
  - Bones 24,500-26,500 years BP
- Charcoal:
  - 26,250 ±1120 year BP

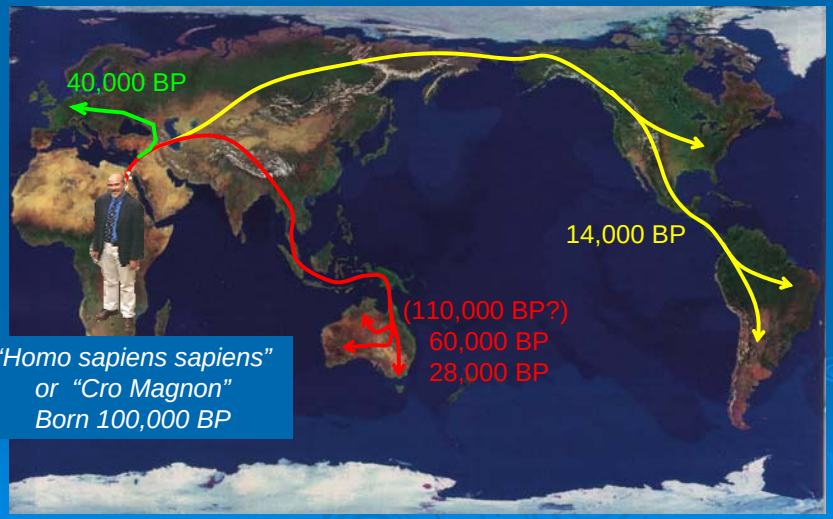


http://www-personal.une.edu.au/~pbrown3/AusOrigins.html

Humanity in Australia

Archaeological site	Years BP	Dating method
Malakunanja II	50,000	Thermoluminescence
Upper Swan	39,500±2300-1800	^{14}C on charcoal
Mandu Mandu Creek	34,200±1050	^{14}C on charcoal
Sandy Creek	31,900 +700/-600	^{14}C on charcoal
Lake Mungo	31,100±2250-1750	^{14}C on shell
ORS7	30,850±480	^{14}C on charcoal
Nunamira Cave	30,420±690	^{14}C on charcoal
Bone Cave	29,000±520	^{14}C on charcoal
Human skeletal material	Years BP	Dating method
Lake Mungo I	24,700±1270	^{14}C on bone collagen
Coobool Creek 65	14,300±1000	U/Th on bone
Kow Swamp 5 and 9	13,000±280, 9,590±130	^{14}C on shell, ^{14}C bone apatite
Keilor	12,000±100	^{14}C on bone collagen
Nacurrie I	11,440±160	AMS on bone collagen
Roonka 89	6,910±450	^{14}C on bone collagen

Out of Africa



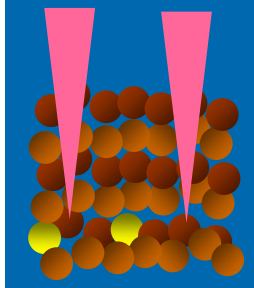
Part 3

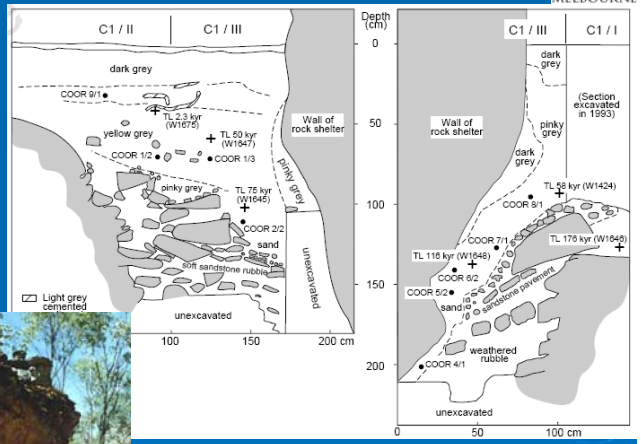
Classical time

Part 4

Controversial time

The Jinmium Rock Shelter





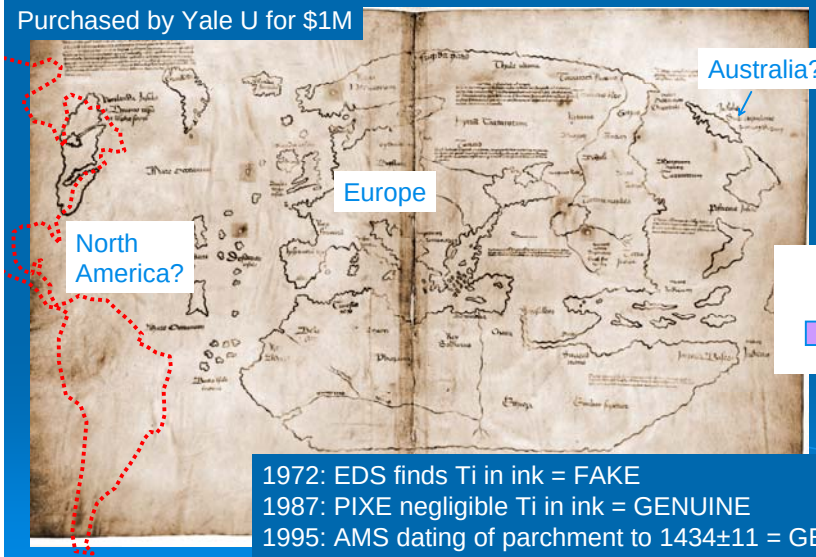
http://www.ansto.gov.au/nugeo/ams/ams_Archaeology.htm

Roberts et al, NATURE VOL 393 28 MAY 1998

~~110,000 years BP?~~
3,870 years BP!

The Vinland Map: Sensational discovery in 1957

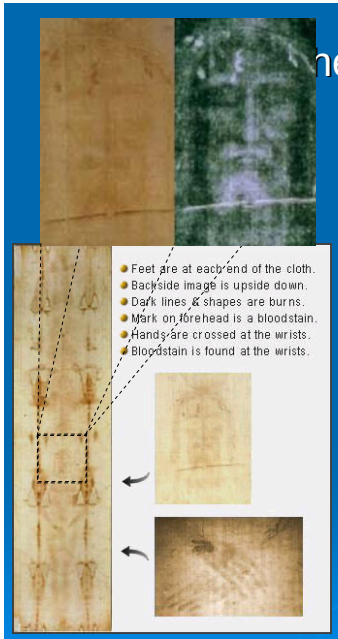
Purchased by Yale U for $1M



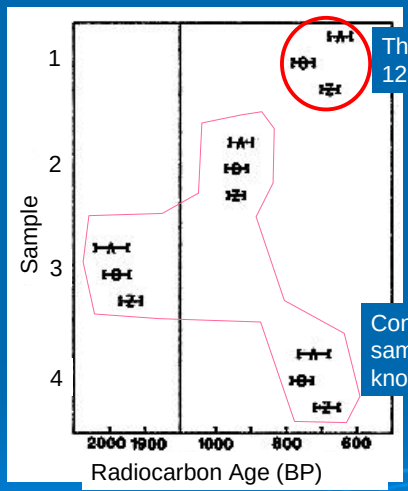
Ink

1972: EDS finds Ti in ink = FAKE
1987: PIXE negligible Ti in ink = GENUINE
1995: AMS dating of parchment to 1434±11 = GENUINE
2002: Raman finds Ti in ink particles = FAKE

ne Shroud of Turin



http://shroud.wikispaces.com/graphic1



The Shroud: 1260-1390

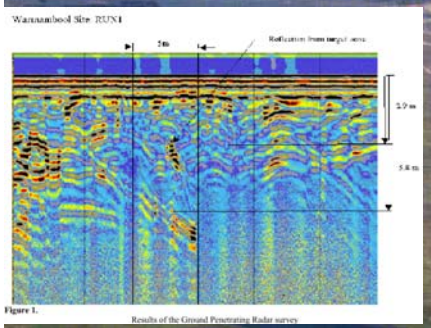
Control samples of known ages

FIG.1 Mean radiocarbon dates, with a ±1 *sd* (*sd* = standard deviation) errors, of the Shroud of Turin and control samples, as supplied by the three laboratories (A, Arizona; O, Oxford; Z, Zurich) (See also Table 2.) The shroud is sample 1, and the three controls are samples 2-4. Note the break in age scale. Ages are given in yr BP (years before 1950). The age of the shroud is obtained as AD 1260-1390, with at least 95% confidence.

Damon et al, Nature, Vol. 337, No. 6208, pp. 611-615, 16th February, 1989

1521: Wreck of the Mahogany ship?

2000: Ancient timber discovered in dune



Excavation finds no Mahogany shipwreck!

Conclusion

- Physics provides objective methods for telling the age
- Methods available on all time scales
- Age of Earth
- Age of Human artifacts
- Final word not yet written!