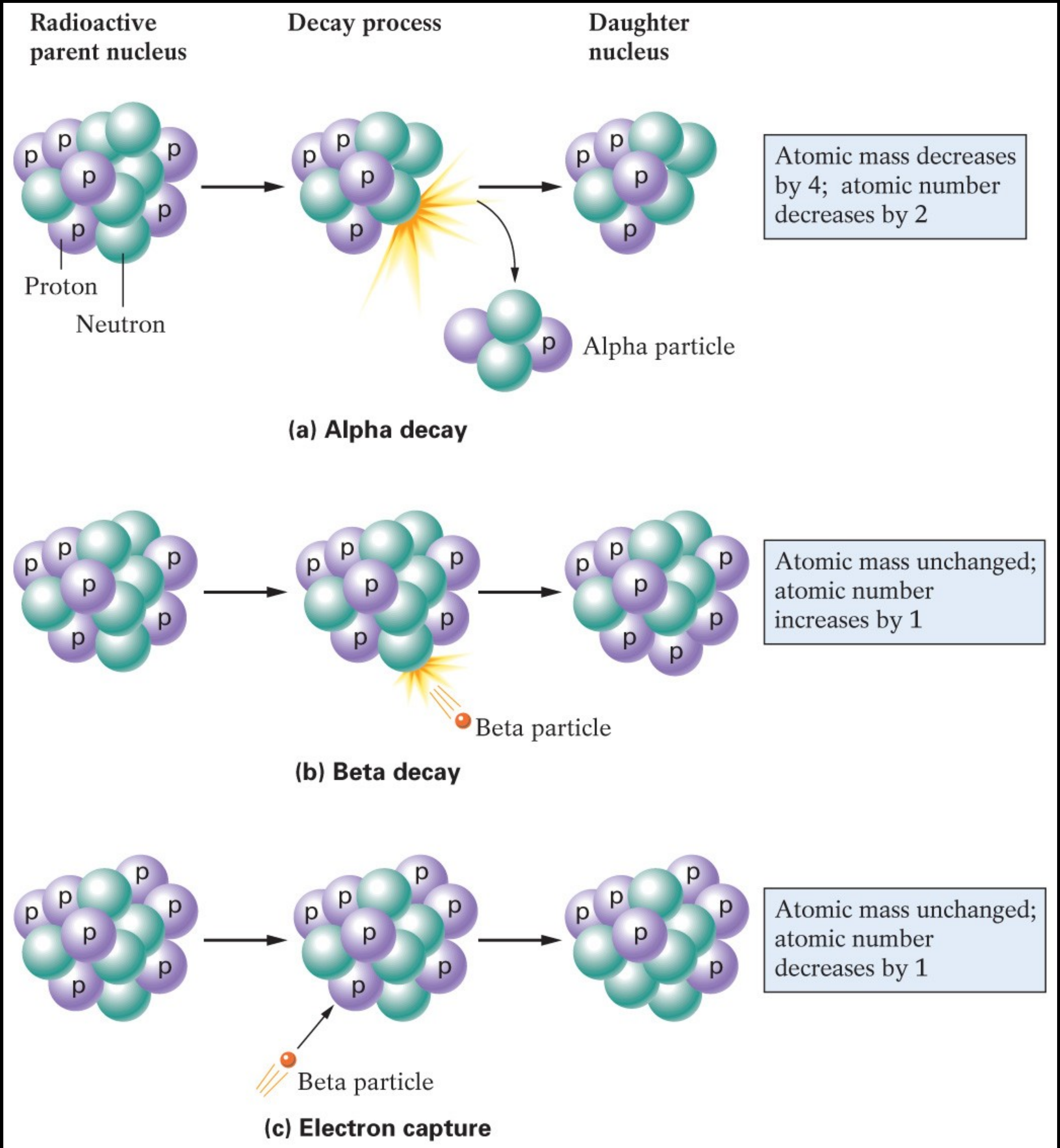
Geocronología Absolura

- Permite darle valor numérico a las escalas estratigráficas contruidas con la bioestratigrafía
- Basada en el decaimiento radocativo de algunos elementos (U, K, C, Rb, Re…)

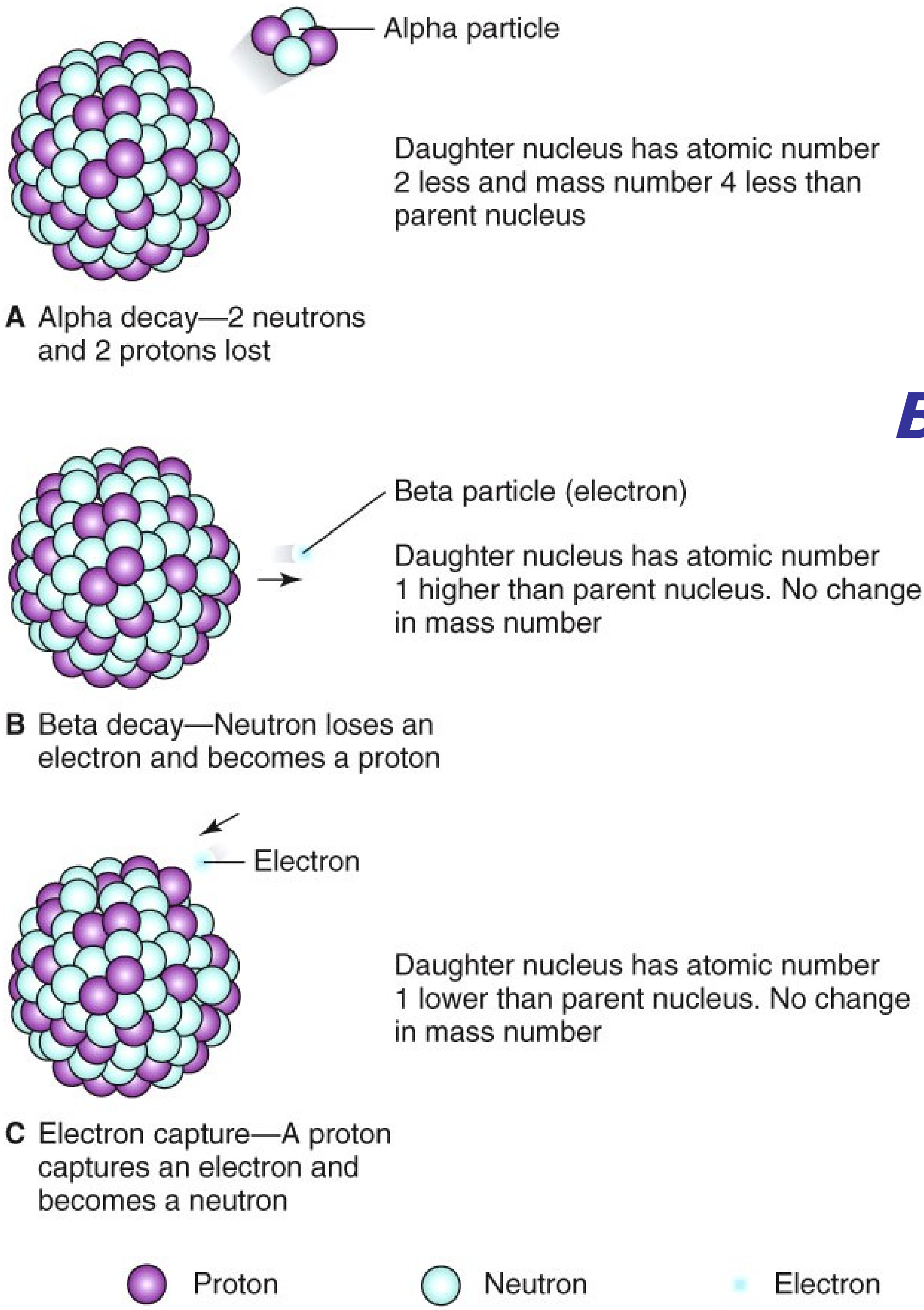


Radioactive decay occurs via three decay processes:

Alpha Decay

Beta Emission

Electron Capture.



Alpha decay

particle has 2 neutrons and 2 protons

U^{238} ⟶ Th^{234}

92 protons 90 protons

Beta decay ($n^0 = p^+ + e^-$)

breakdown of neutron into an electron and a proton and loss of the electron to leave a proton (result is gain of one proton)

K^{40} ⟶ Ca^{40}

19 protons 20 protons

electron capture ($e^- + p^+ = n^0$)

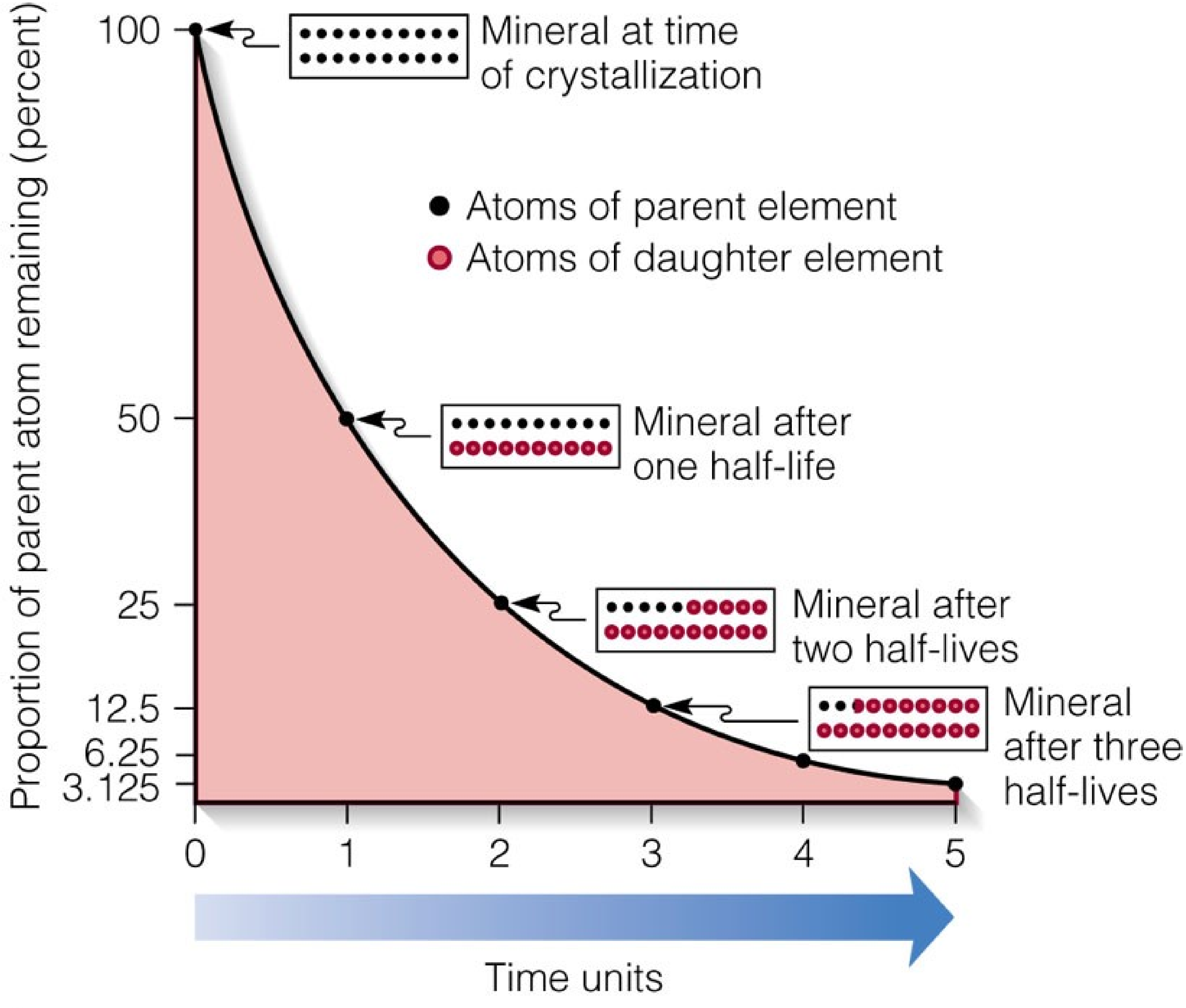
capture of an electron by a proton and change of proton to neutron (result is loss of proton)

K^{40} ⟶ Ar^{40}

19 protons 18 protons

Isotopic Dating

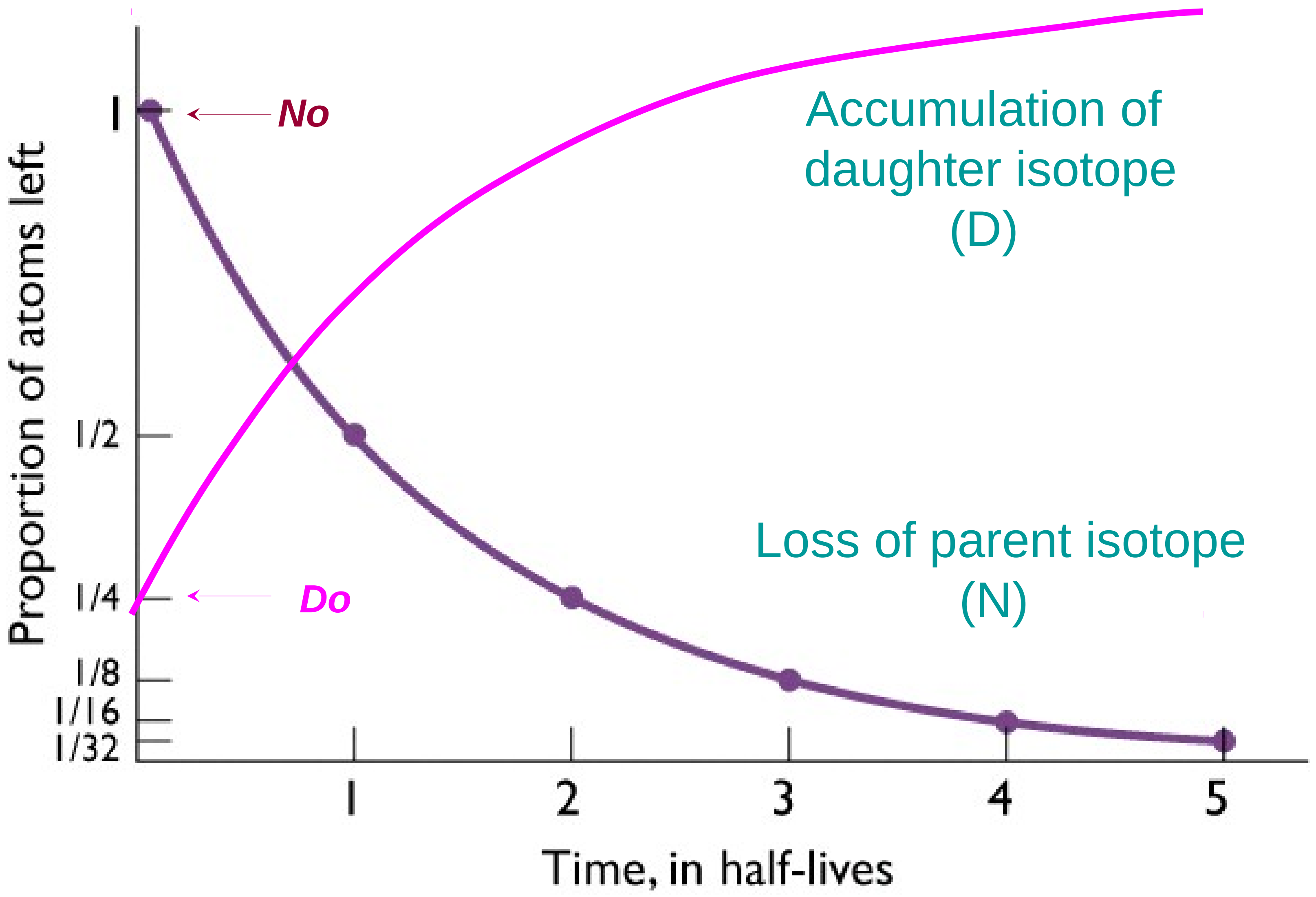
- Radioactive elements (parents) decay to stable, non-radioactive elements (daughters)
- The rate at which this decay occurs is constant and known
- If we know the rate of decay and the amount present of parent and daughter we can calculate how long this reaction has been occurring.

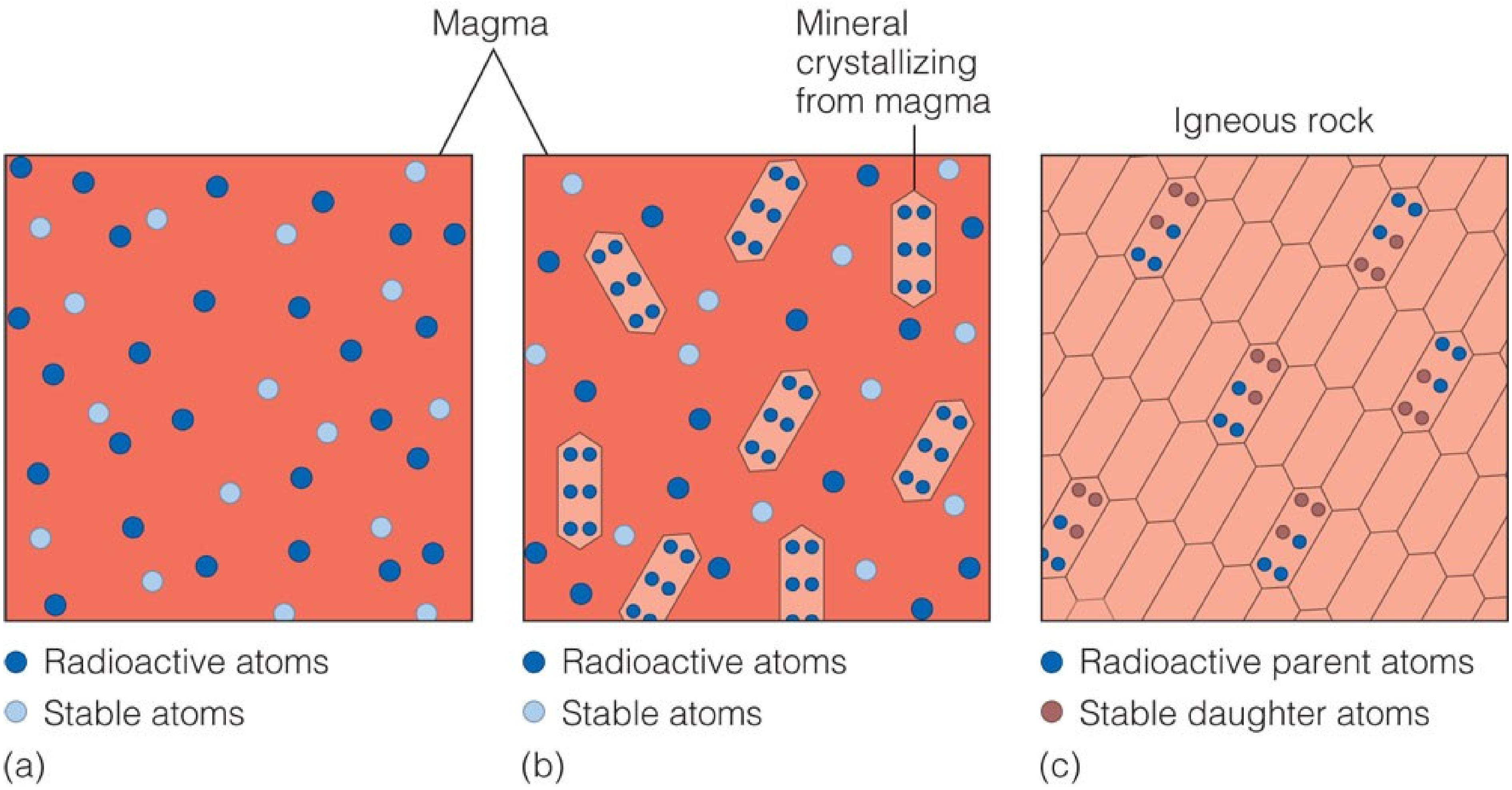


Proportion of parent atom remaining (percent)
100
50
25
12.5
6.25
3.125
Mineral at time of crystallization
Atoms of parent element
Atoms of daughter element
Mineral after one half-life
Mineral after two half-lives
Mineral after three half-lives
0
1
2
3
4
5
Time units

Half Lives

The amount of time required for half the remaining material to decay





Magma
Mineral
crystallizing
from magma
Igneous rock
Radioactive atoms
Stable atoms
(a)
Radioactive atoms
Stable atoms
(b)
Radioactive parent atoms
Stable daughter atoms
(c)

D_0

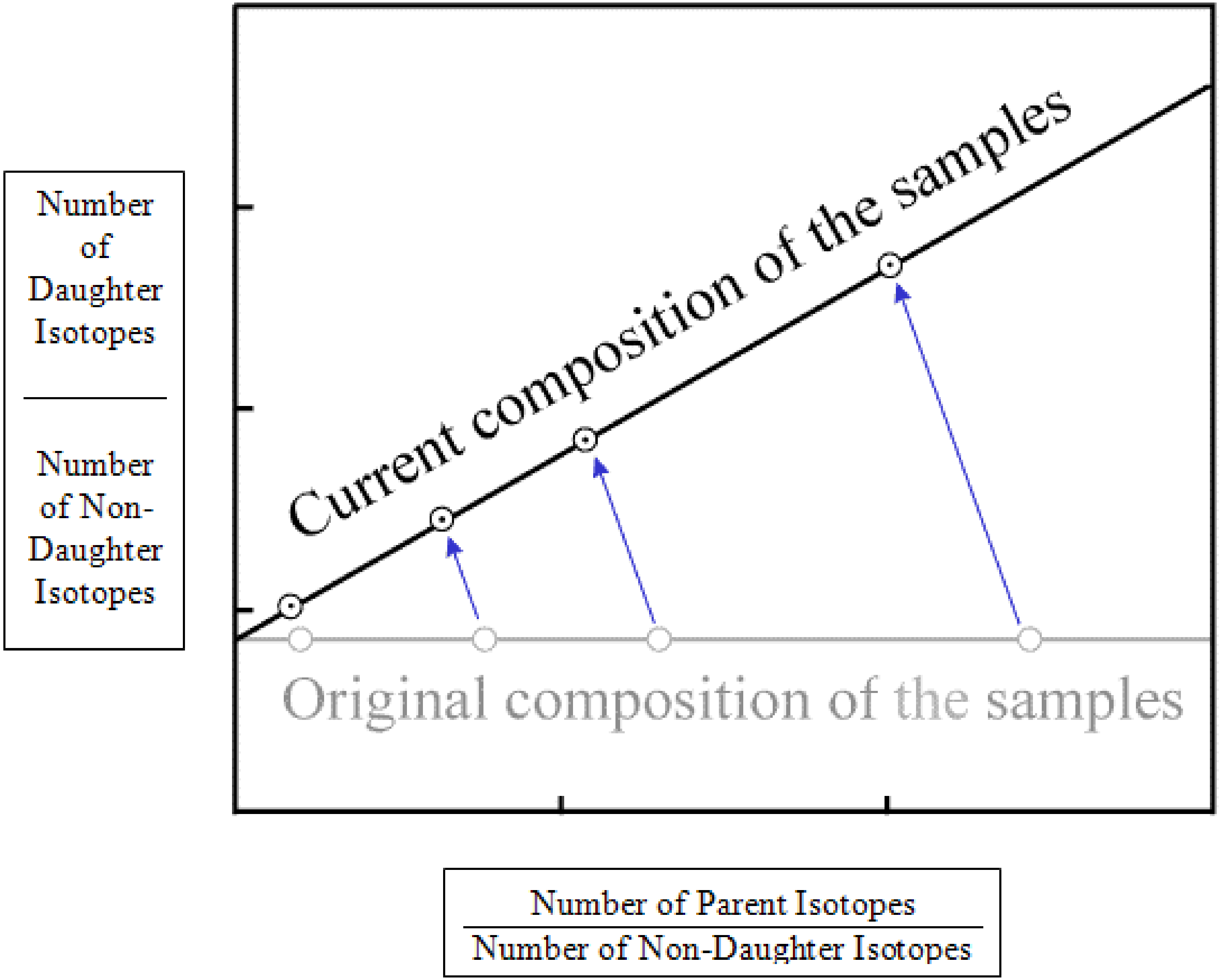
λ : *constante de decaimiento radioactivo*

Five Radioactive Isotope Pairs

Five Radioactive Isotope Pairs

Isotopes: *Parent*	Isotopes: *Daughter*	Half-Life (Years)	Effective Dating Range of Parent (Years)	Minerals and Rocks That Can Be Dated
Uranium 238	Lead 206	4.5 billion	10 million to 4.6 billion	Zircon Uraninite
Uranium 235	Lead 207	704 million		
Thorium 232	Lead 208	14 billion	48.8 billion	Muscovite Biotite Potassium feldspar Whole metamorphic or igneous rock
Rubidium 87	Strontium 87	4.6 billion	10 million to 4.6 billion	
Potassium 40	Argon 40	1.3 billion	100,000 to 4.6 billion	Glauconite Muscovite Biotite Hornblende Whole volcanic rock

Isócronas

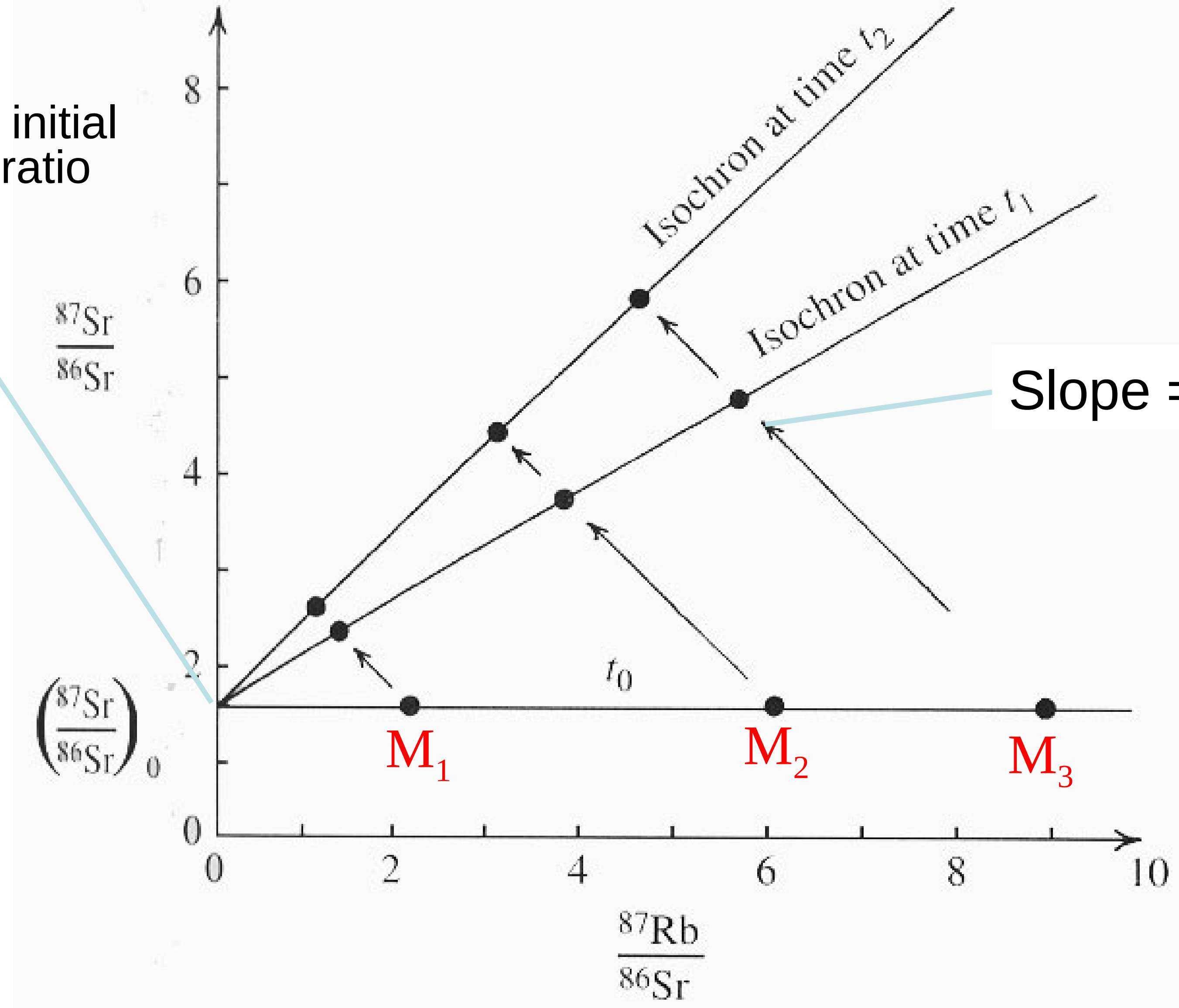


Current composition of the samples
Original composition of the samples
Number of Daughter Isotopes
Number of Non-Daughter Isotopes
Number of Parent Isotopes
Number of Non-Daughter Isotopes

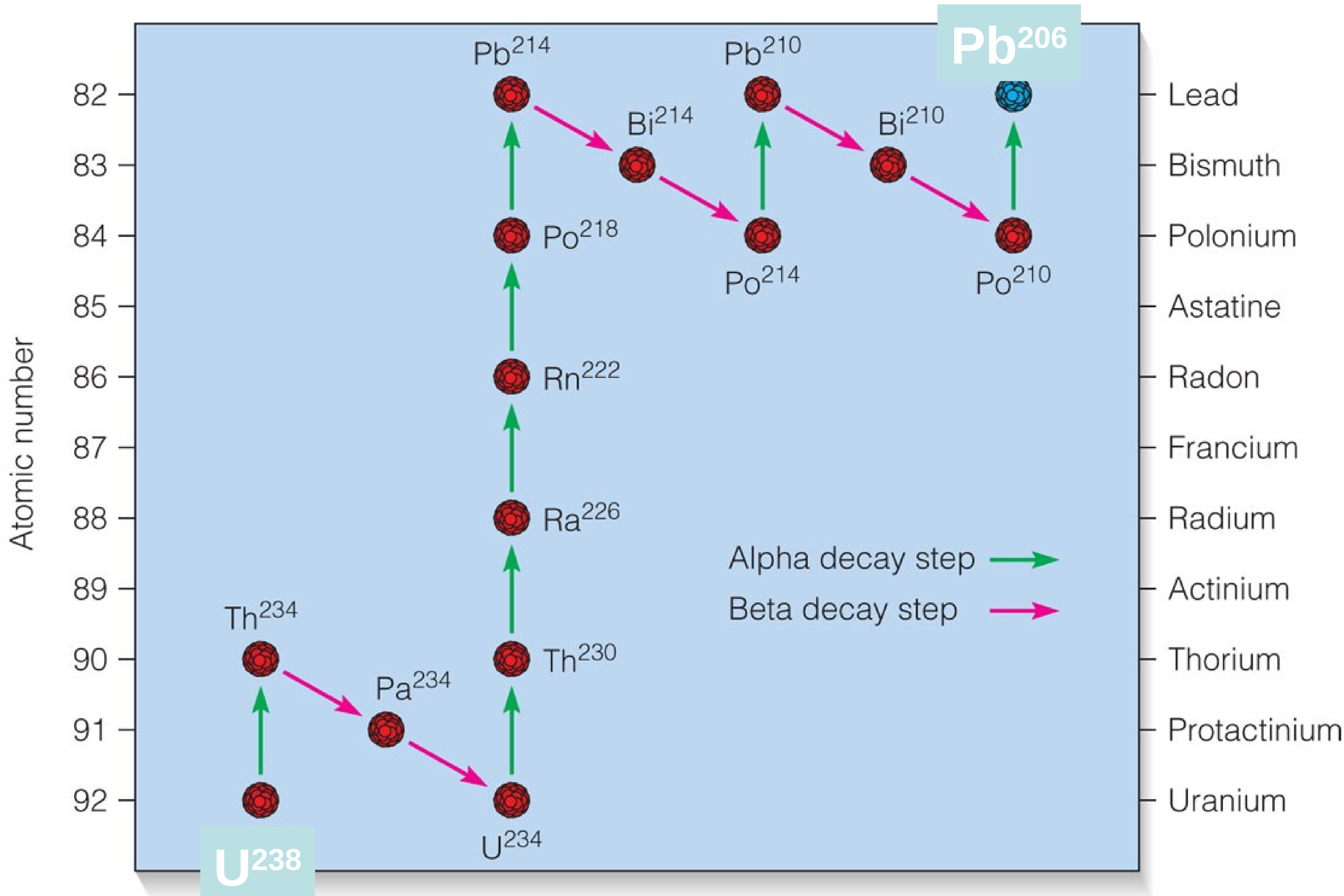
Rb/Sr Isochron Method

Intercept = initial daughter ratio

Slope = $e^{\lambda t}-1$



Microfotografía. Cristal de Botita visto con Luz Polaridada

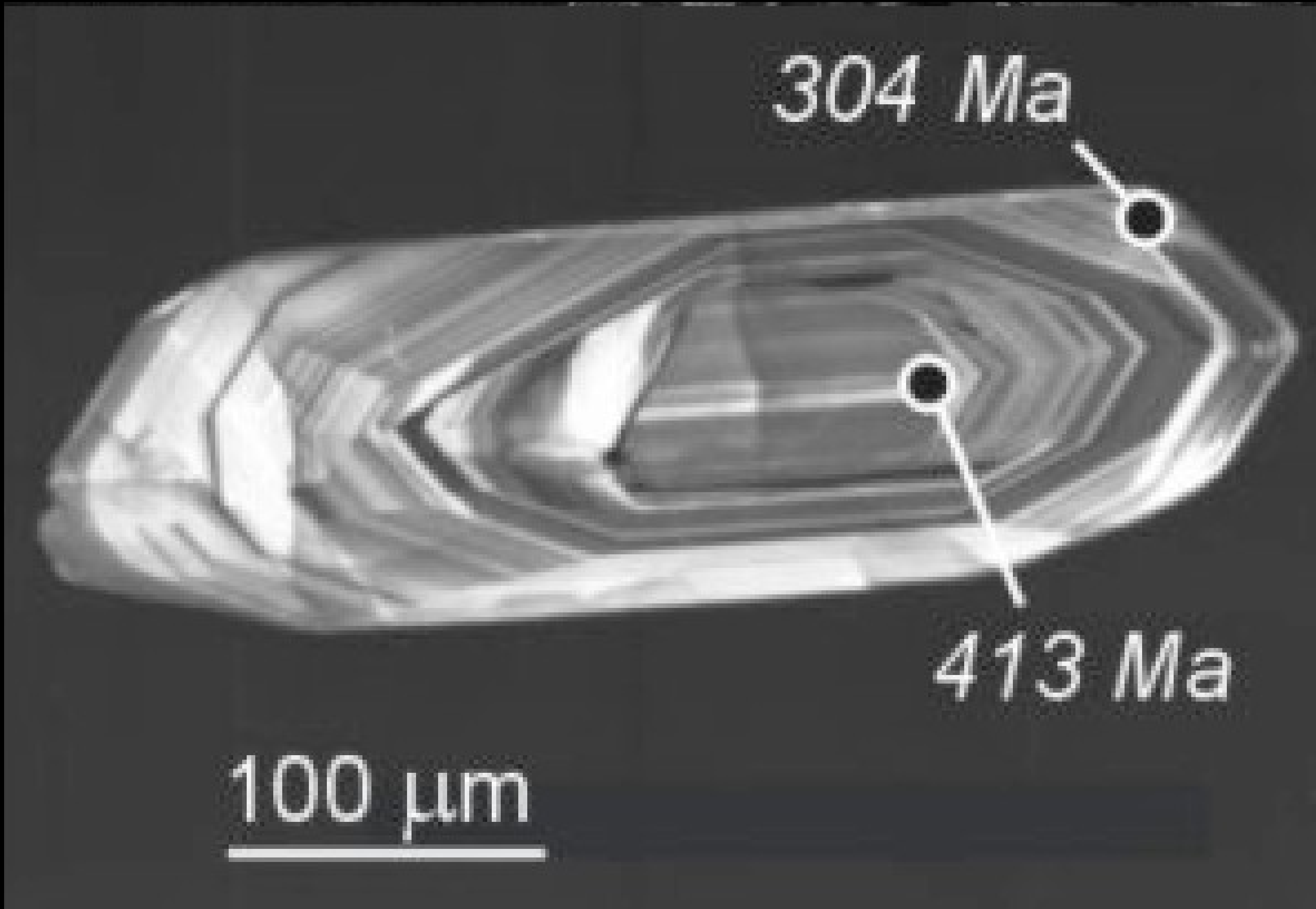


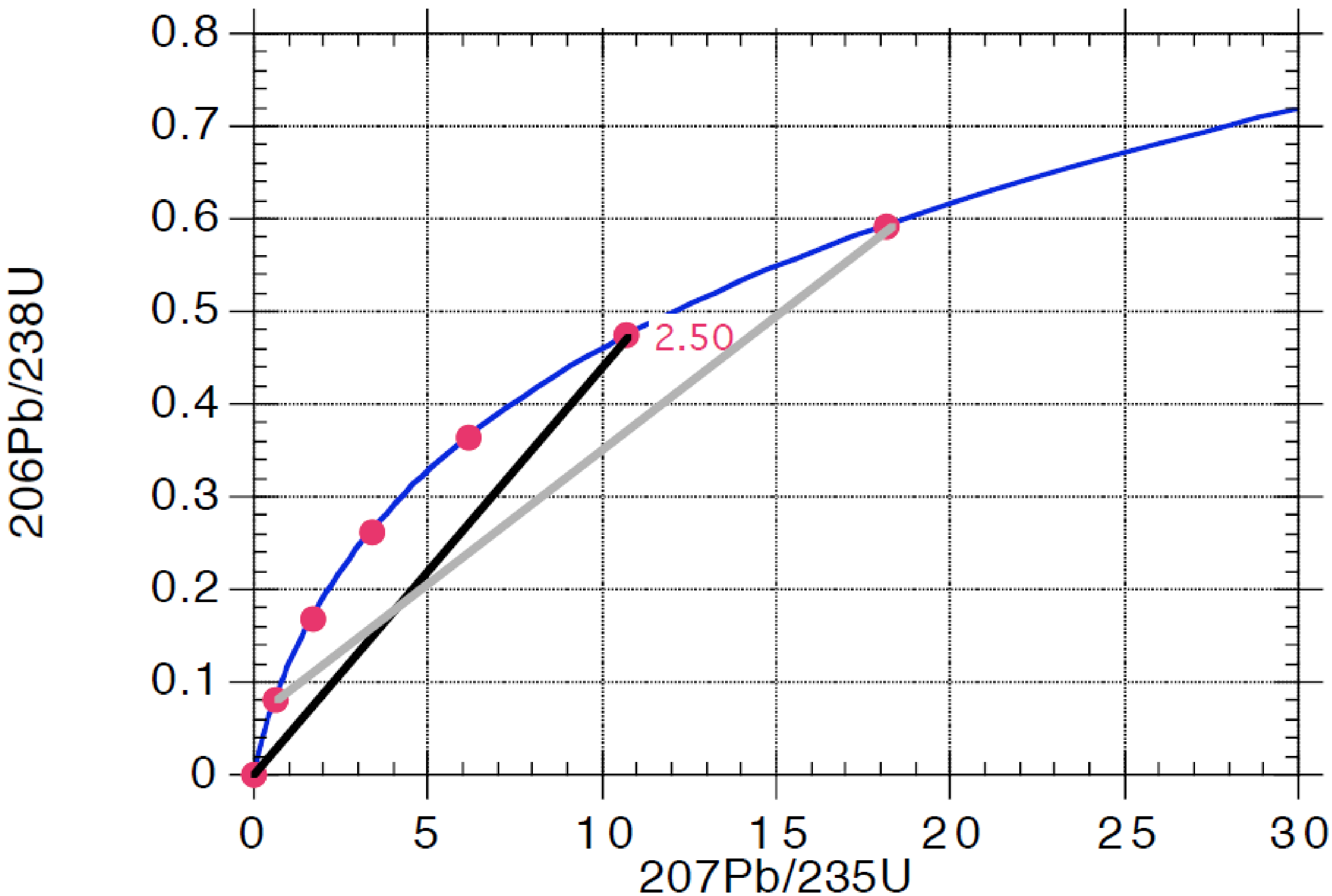
Pb206
Pb214
Pb210
Bi214
Bi210
Po218
Po214
Po210
Rn222
Ra226
Th234
Th230
Pa234
U234
U238
Atomic number
82
83
84
85
86
87
88
89
90
91
92
Lead
Bismuth
Polonium
Astatine
Radon
Francium
Radium
Actinium
Thorium
Protactinium
Uranium
Alpha decay step
Beta decay step

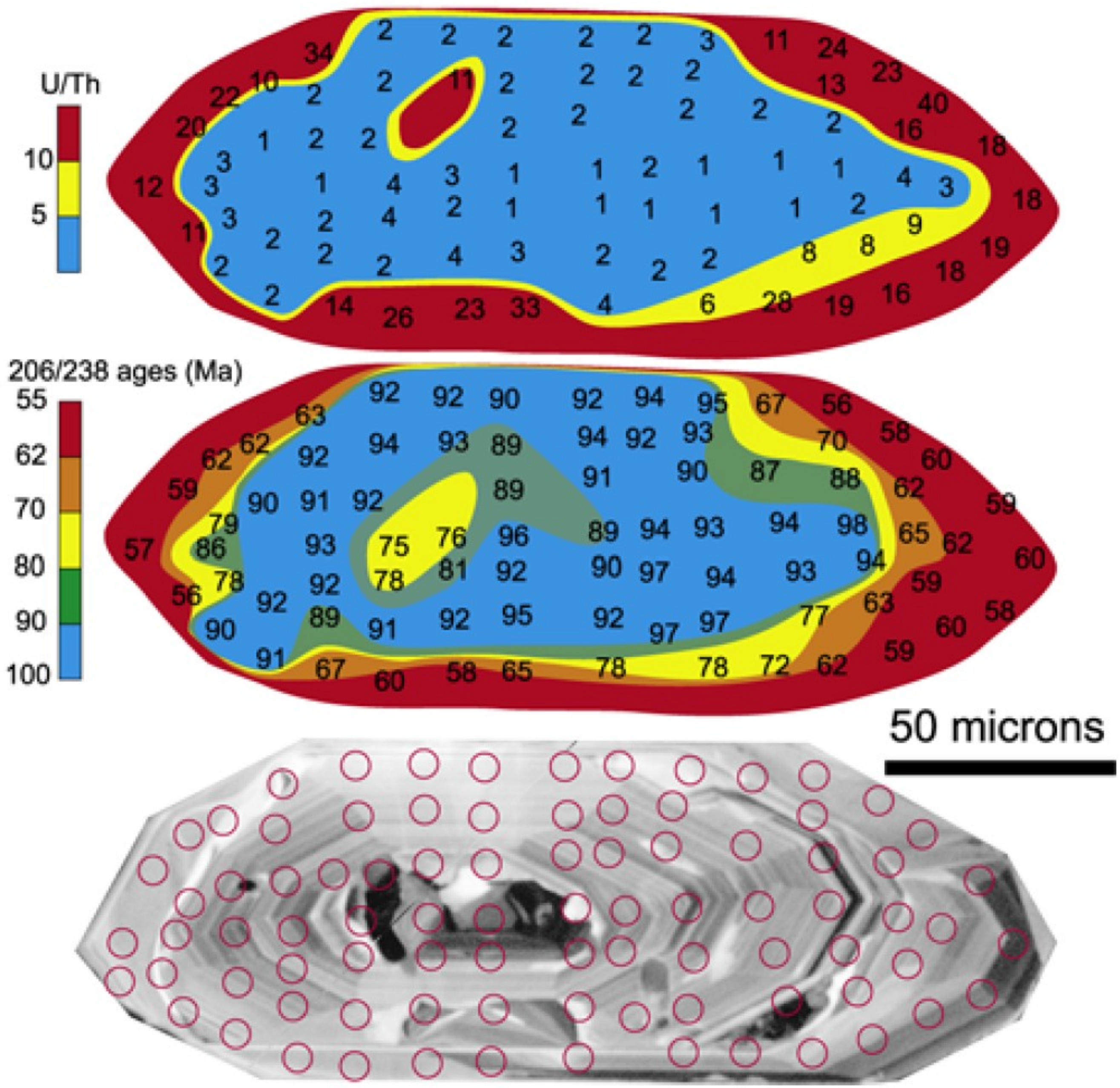
Zircon Laser Ablation Pit

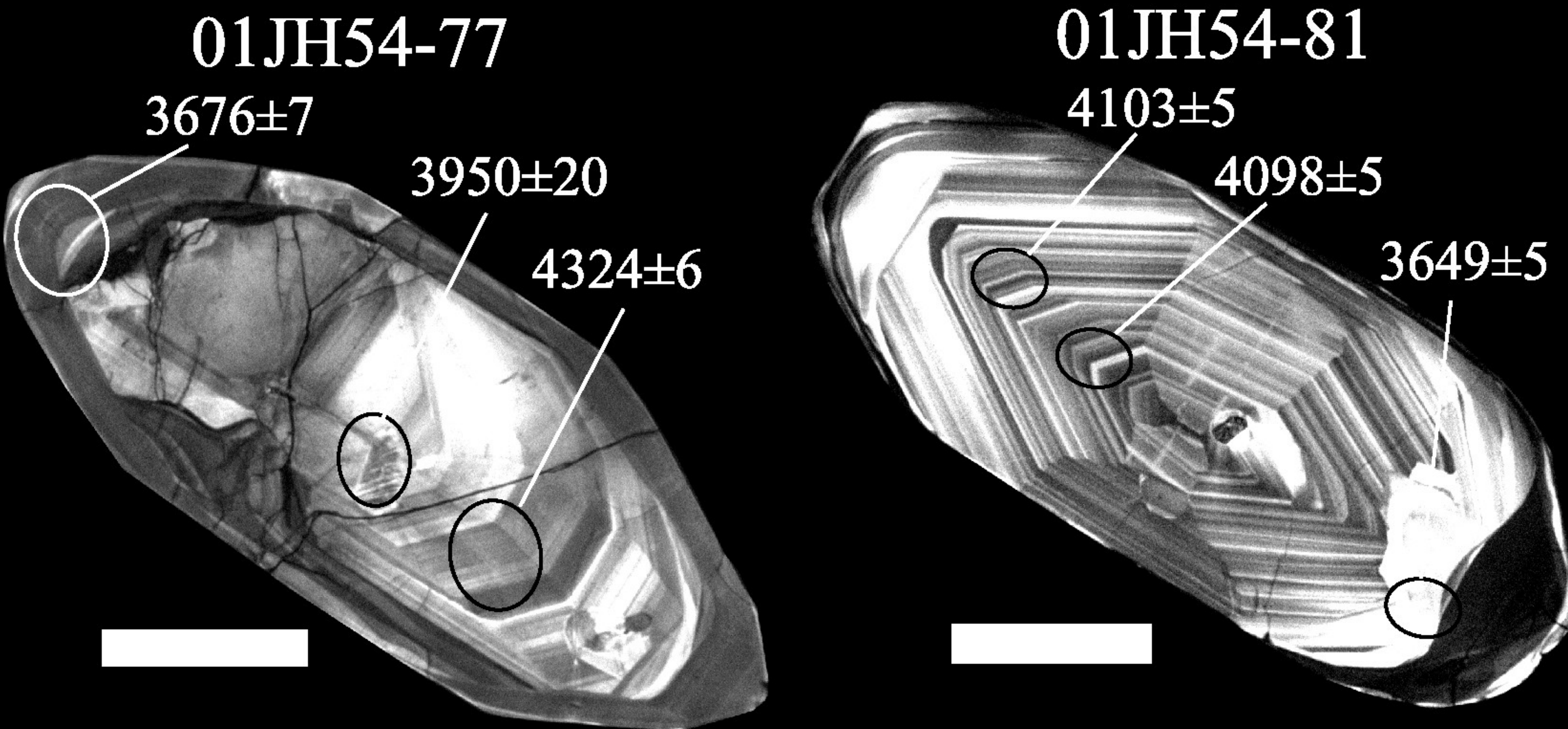
SHRIMP Mass Spectrometer

U/Pb Zircon




206Pb/238U
207Pb/235U
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
2.50

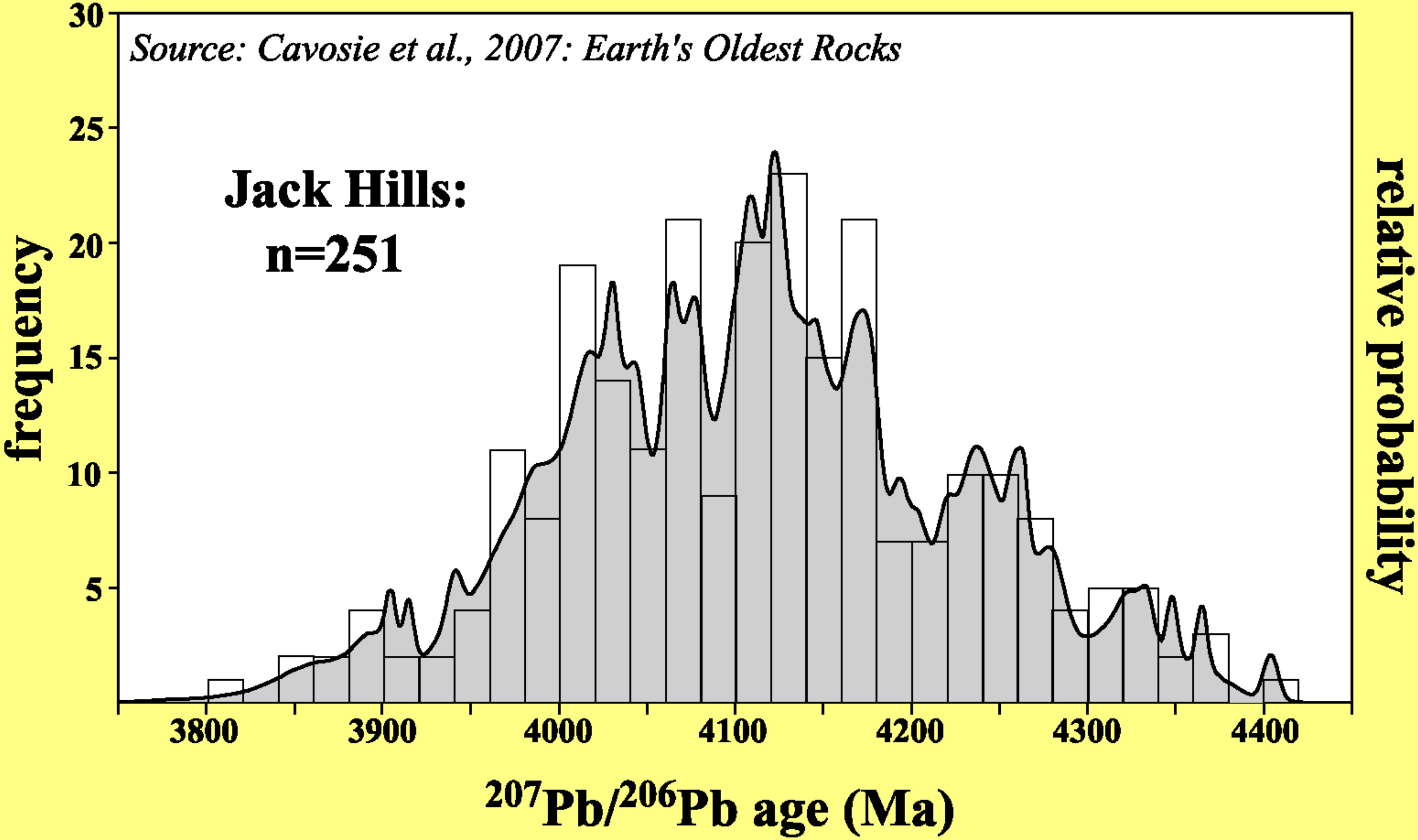

U/Th
10
5
206/238 ages (Ma)
55
62
70
80
90
100
50 microns



Source: Cavosie et al., 2004 Precam. Res.; Valley et al., 2006 Science

Jack Hills Zircons, Australia

Age distribution of Jack Hills detrital zircons



180°
140°
100°
60°
0°
60°
100°
140°
180°
Arctic Ocean
Greenland
Slave
Superior
Buffalo
Cordillera
Nikos
North America
Wyoming
Colorado
Atlantic Ocean
Gneiss Region
Kola
Karelia
Scandian
Europe
Volgo Uralia
Sarmatia
Variscan Vosges
Alps
Pohorje
Ukrainian
Ronda
West Africa
Africa
Congo
Tanzania
Zimbabew
Kaapvaal
Anabar
Siberia
Vitim
Sharyzhalgai
Aldan
Shavaryn Saram
Hannuoba
Asia
Tarim
North China
Yangtze
India
Pacific Ocean
Sulawesi
Indian Ocean
Pilbara
Australia
Yilgarn
Gawler
Rio San Juan
Amazonia
South America
Sao Francisco
Rio de la Plata
Pacific Ocean
Atlantic Ocean
Antactic
Jetty Peninsula
60°
40°
20°
0°
20°
40°
60°
Garnet peridotite xenolith locality
Orogenic garnet peridotite locality
Phanerozoic
Proterozoic
Archean craton

A typical rock exposure in the Godthaabsfjord region, Greenland

Moorbath S Notes Rec. R. Soc. doi:10.1098/rsnr.2009.0004

NOTES & RECORDS OF THE ROYAL SOCIETY

The oldest rocks

~4.4 ? Ga

- ~ 4.4. Ga oldest minerals (zircons , Jack Hills, Australia)
- 3.8 - 4.1 Ga Tonalite-Trondhjemite gneiss complexes (North America, China, Greenland, Australia)
- 3.75 - 3.7 Ga Isua Greenstone belt + 3.65 Amitsoq Gneiss
- >3.5 - 3.0 Ga Australia, South Africa: Pilbara and Barberton Greenstone Belts

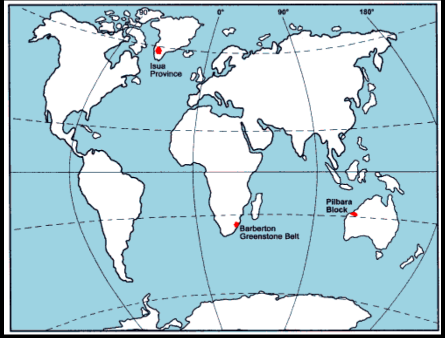
Ocean Earth

~3.4 Ga

transition

~3.3 Ga

continents

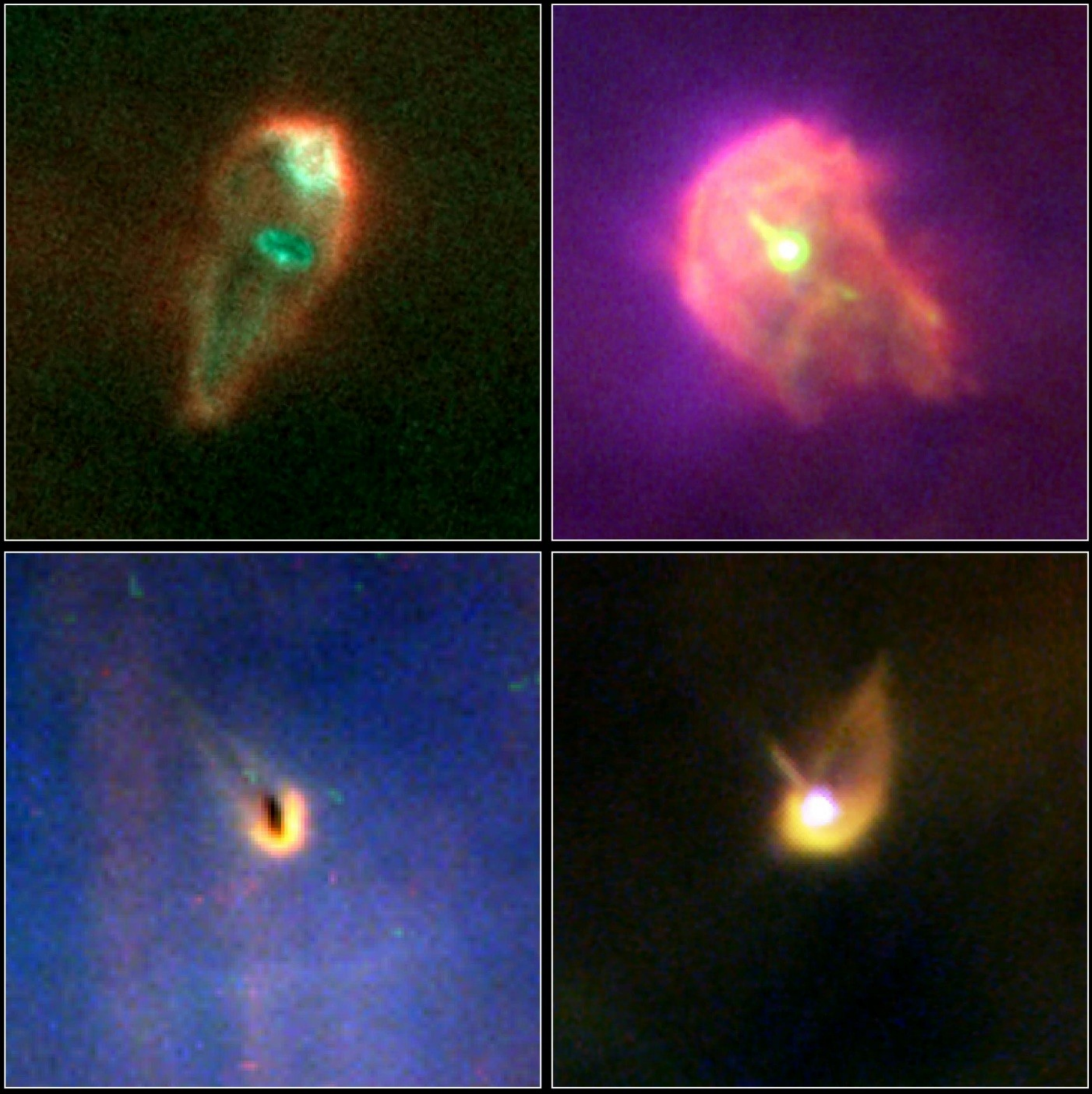


EDAD de la Tierra ?

NASA/Cassini, Sept 2006

“Pilares de la Creación”

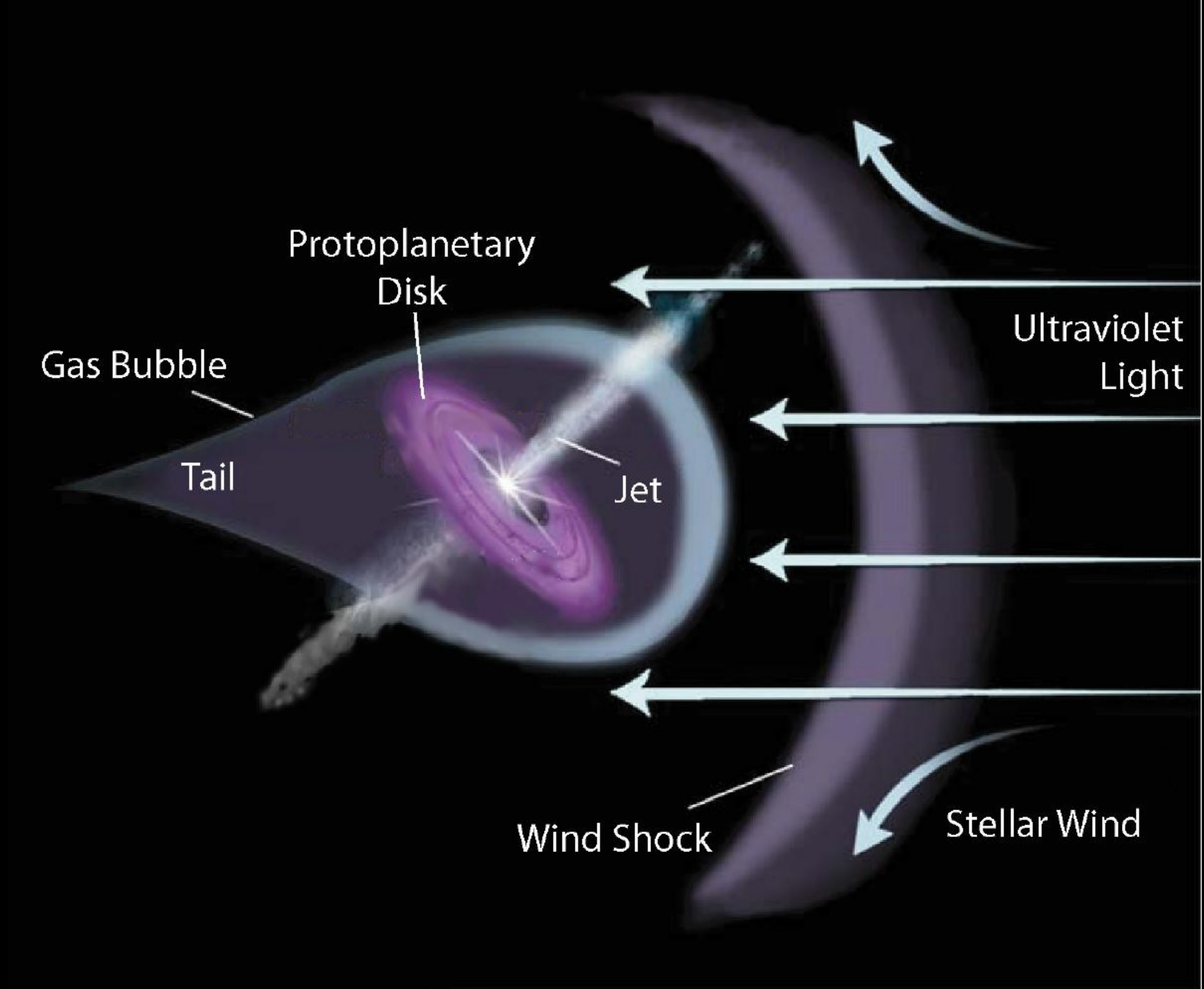
Nebulosa del Aguila

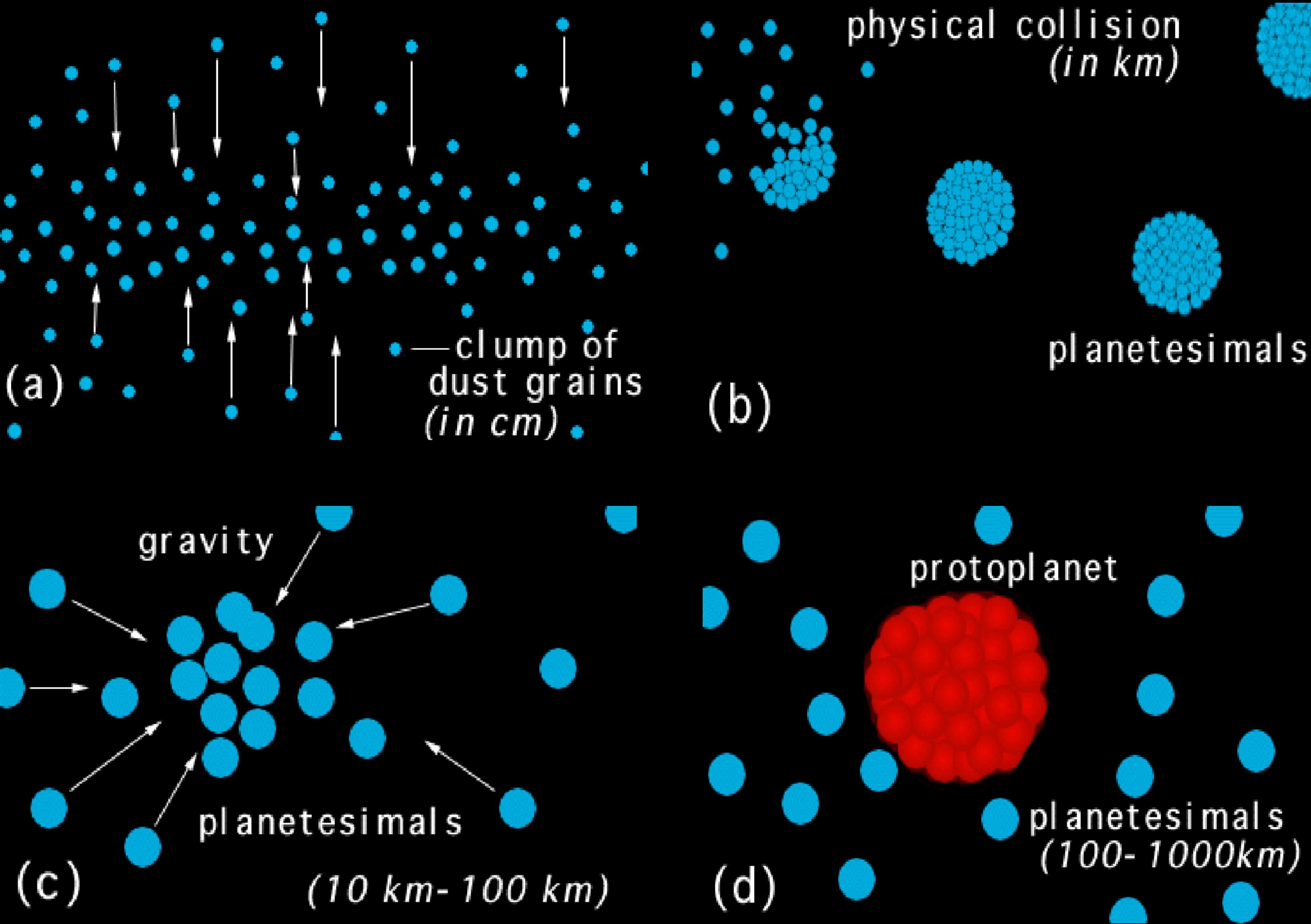


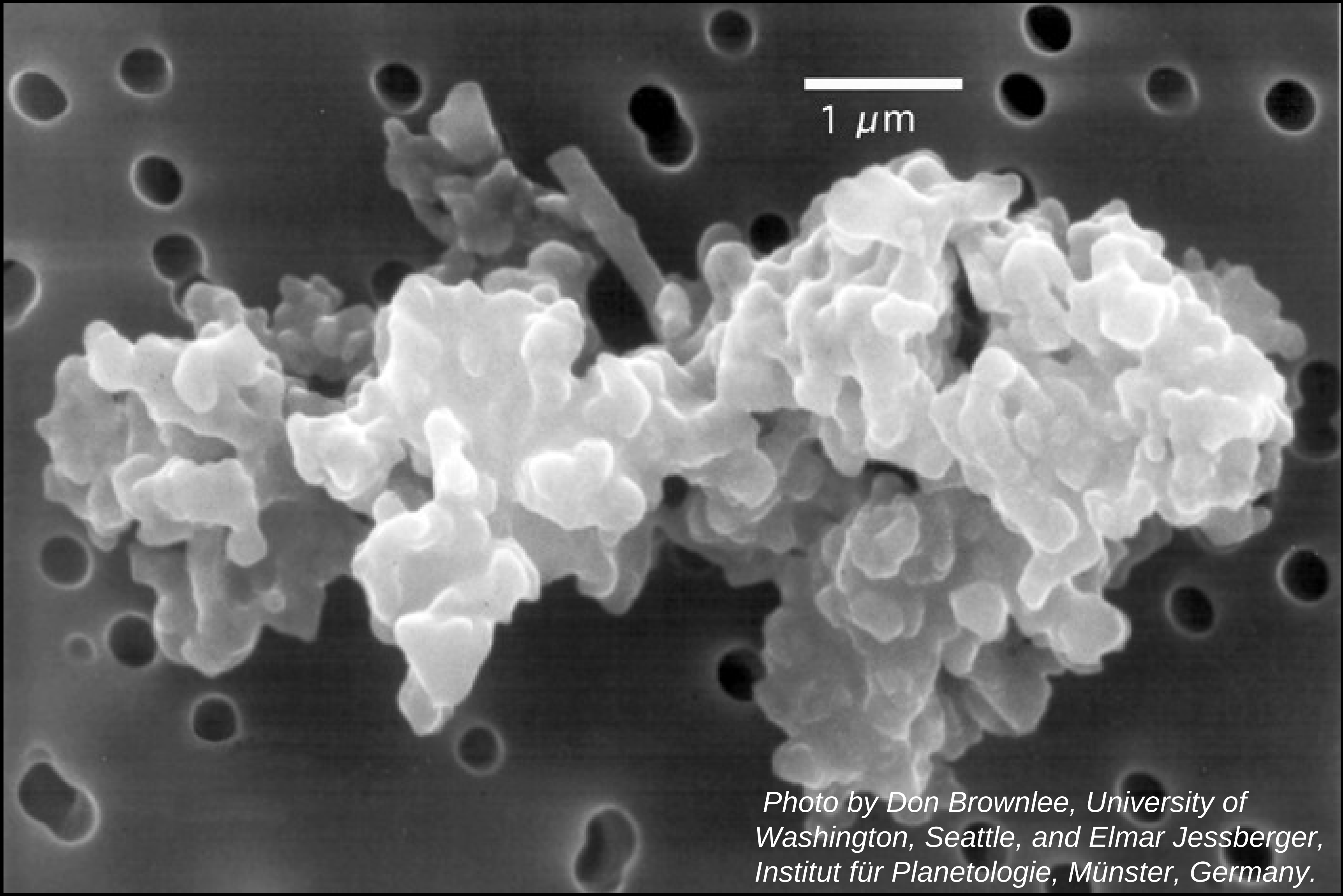
Protoplanetary Disks in the Orion Nebula
Hubble Space Telescope • WFPC2

-A ***Protoplanetary disk*** (or ***Proplyd***) is a rotating circumstellar disk of dense gas surrounding a young newly formed star, a T Tauri star or Herbig star

-***Protostars*** typically form from molecular clouds consisting primarily of molecular hydrogen. When a portion of a molecular cloud reaches a critical size, mass, or density, it begins to collapse under its own gravity


Protoplanetary
Disk
Gas Bubble
Tail
Jet
Ultraviolet
Light
Wind Shock
Stellar Wind


clump of
dust grains
(in cm)
(a)
physical collision
(in km)
planetesimals
(b)
gravity
planetesimals
(c)
(10 km-100 km)
protoplanet
planetesimals
(100-1000km)
(d)

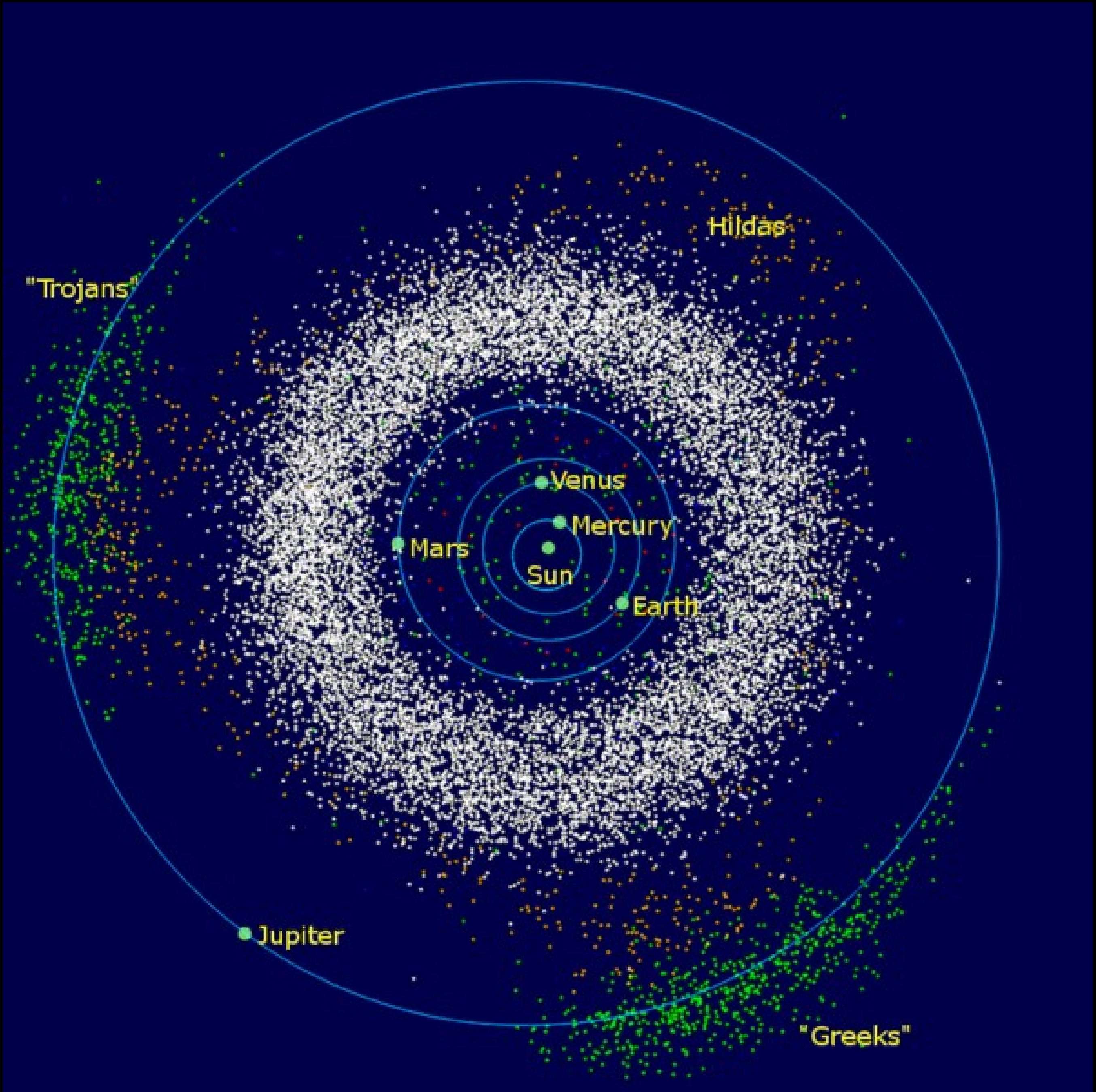


Scanning electron microscope image of an interplanetary dust particle that has roughly en:chondritic elemental composition and is highly rough (chondritic porous: "CP")

Asteroid 951 Gaspra is one of the best-studied asteroids. Photograph by spacecraft Galileo /1991.

-Subtle colour variations have been exaggerated to highlight changes in reflectivity, surface structure and composition.

Gaspra is about 20 kilometres long and orbits the Sun in the main asteroid belt between Mars and Jupiter.



Hildas
"Trojans"
Venus
Mercury
Mars
Sun
Earth
Jupiter
"Greeks"

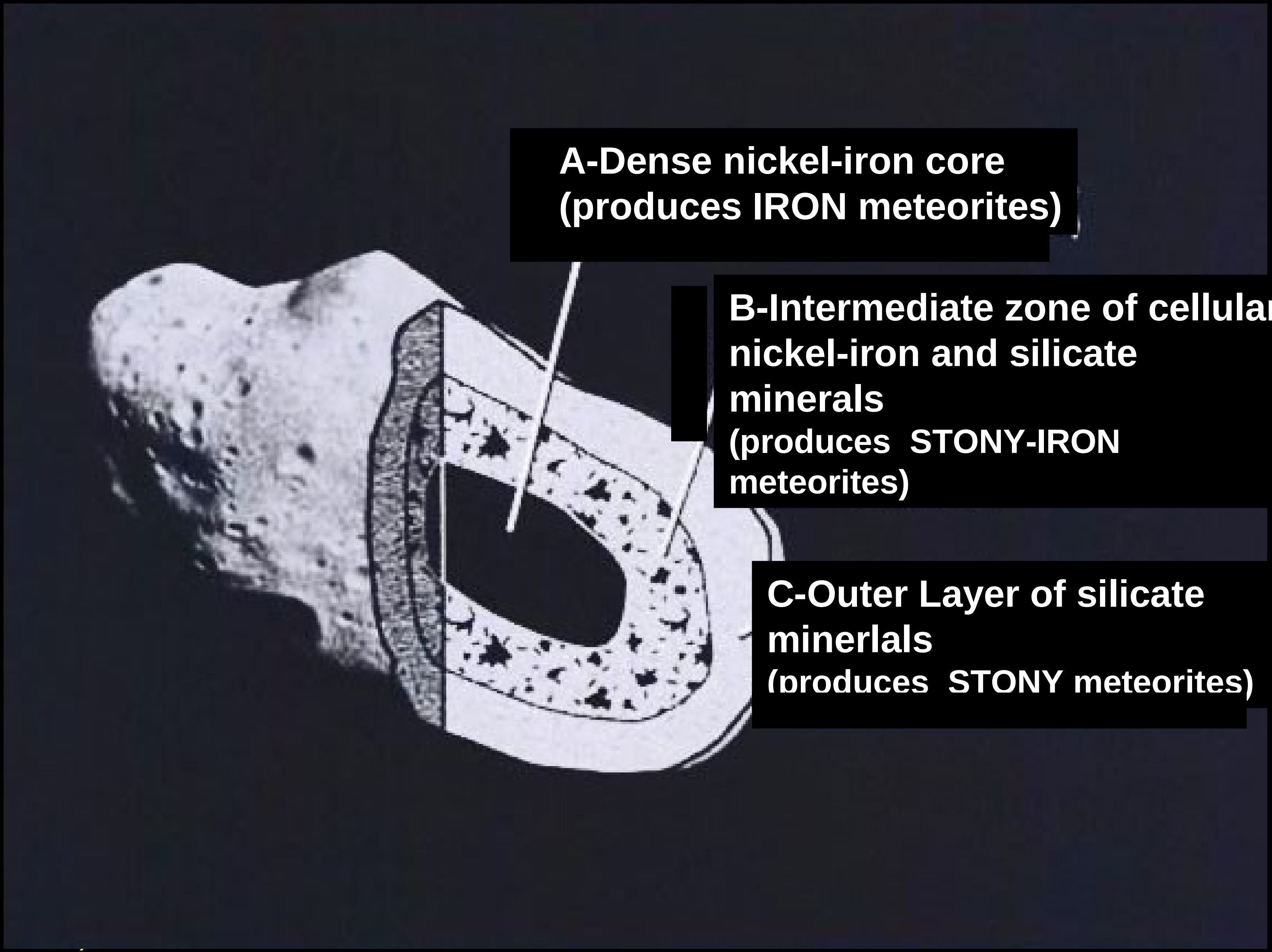
Differentiated Meteorites

-Irons and non-chondrule-bearing stones called Achondrites.

-Achondrites are similar to igneous rocks

METEORIC IRON: kamacite and taenite crystals coexisting in the Fe-Ni alloy are the cause of the "Widmanstatten figures". Analogous terrestrial rocks are not known, but are possible.
(Ward's Catalogue, Rochester NY)

Primitive material in the solar system: Meteorites



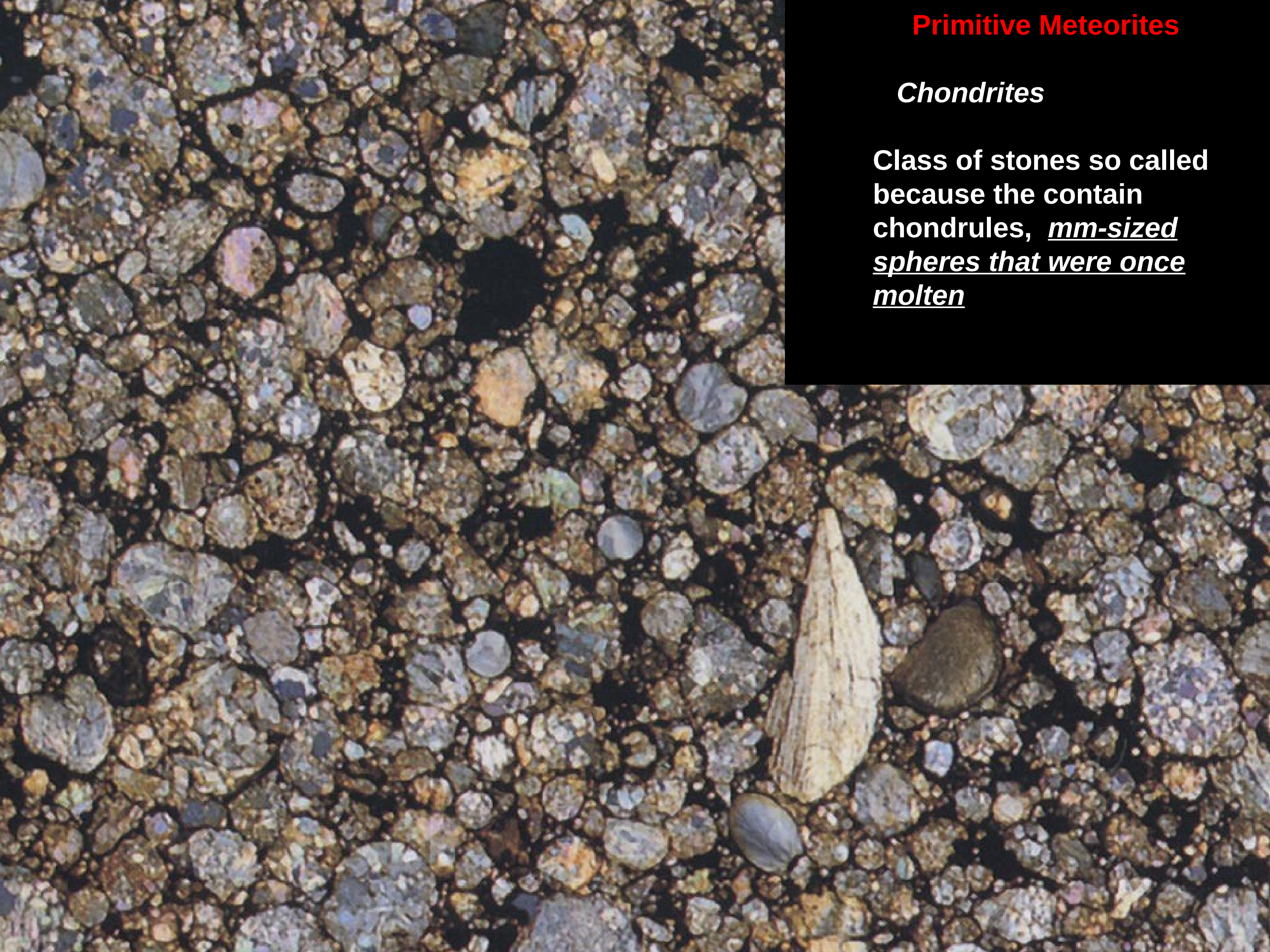
Stony-Iron
Imilac Pallasite

Crater de Imilac, Antofagasta

Primitive Meteorites

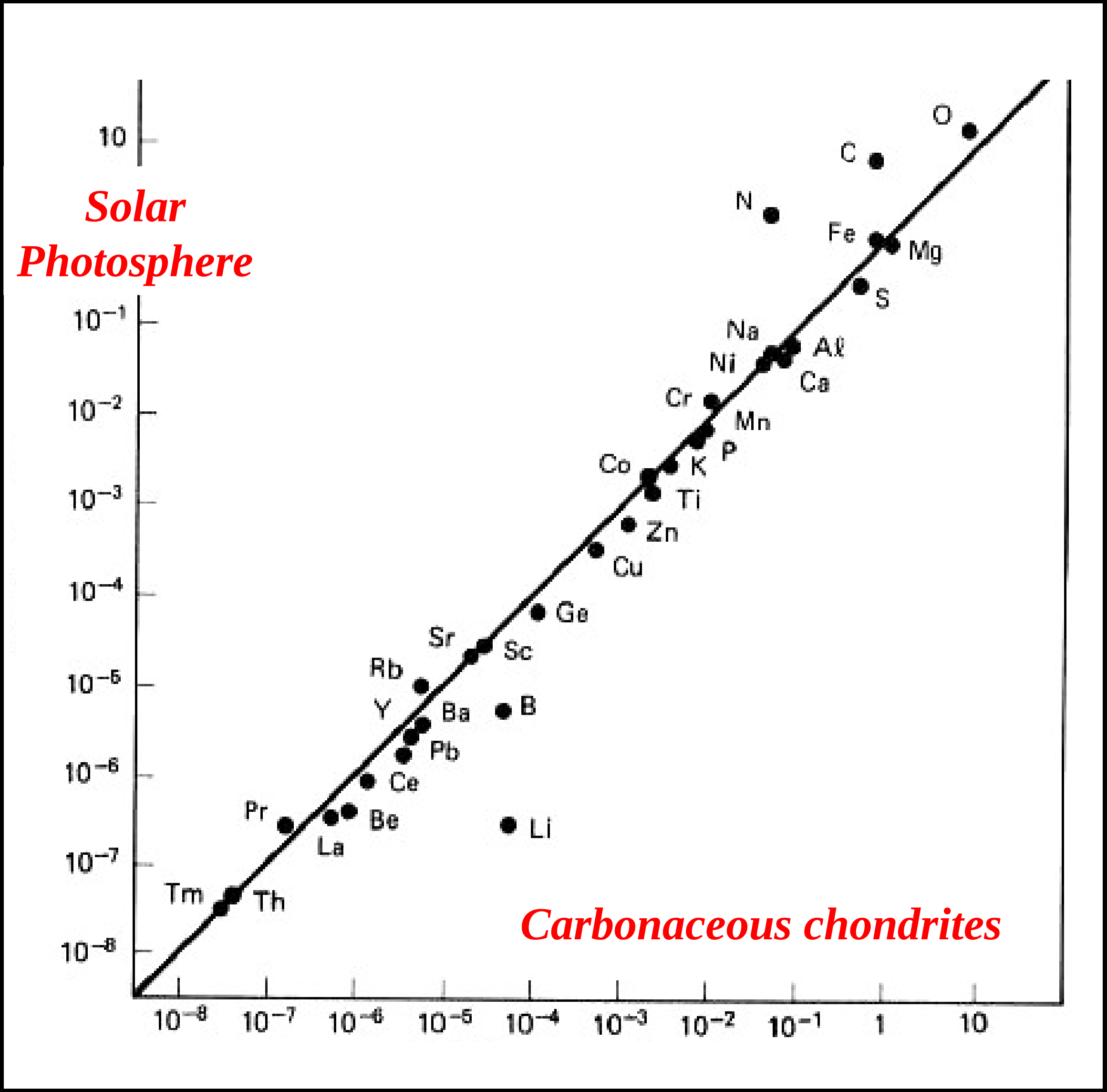
Chondrites

Class of stones so called because the contain chondrules, *mm-sized spheres that were once molten*



-A ***chondrule*** is a spherical, millimetre sized, silicate inclusion found in a type ofmeteorite called embedded in fine-grained interplanetary dust, may form up to 80% of the meteorite of chodrite volume

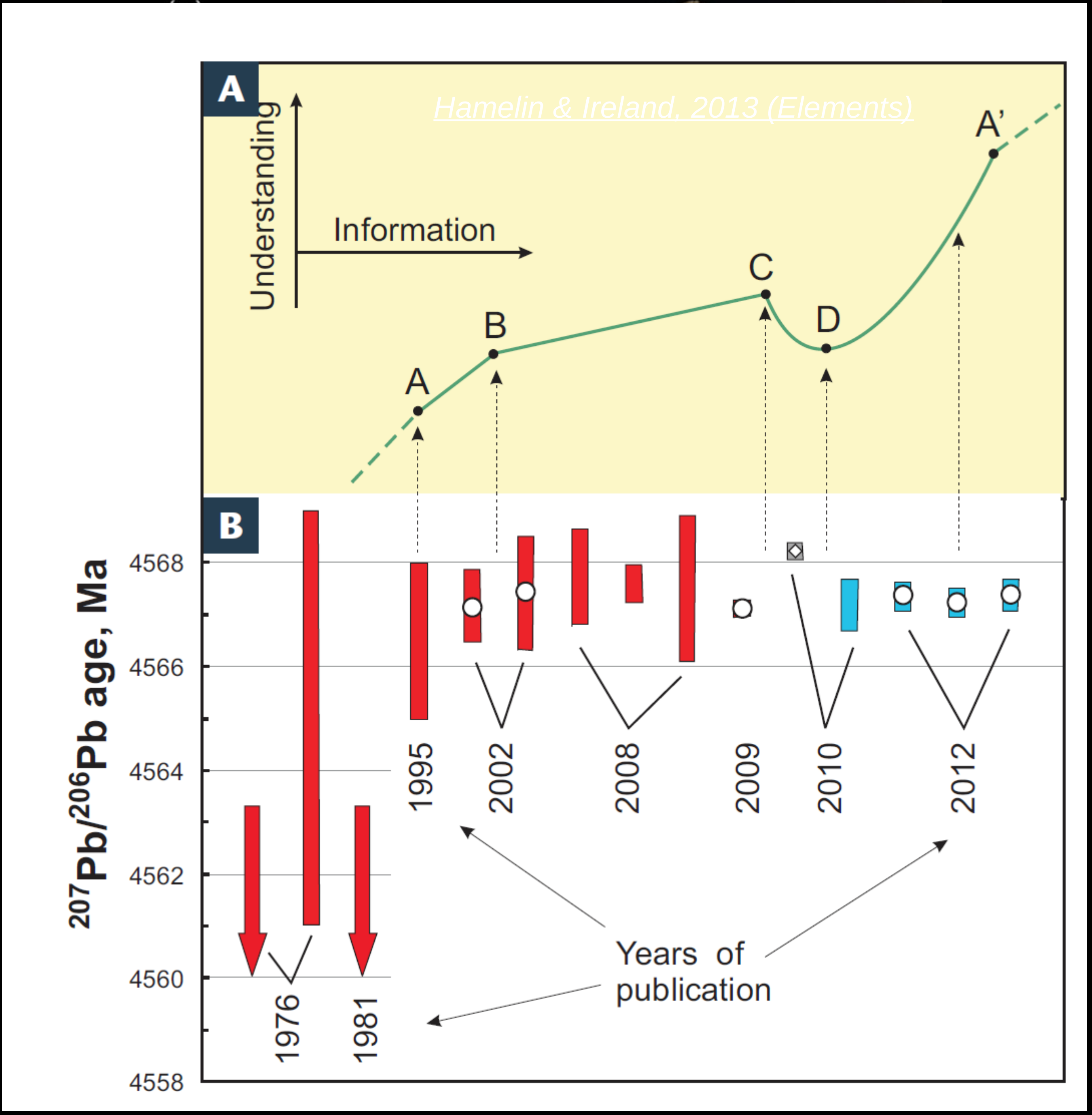
-Made of the minerals olivine and pyroxene (with perhaps smaller amounts of glass, iron and nickel present), ***chondrules are the oldest objects in the Solar System.*** Their spherical nature suggests that they were once molten, and it is thought that they solidified very quickly - indicating that the heat source was a

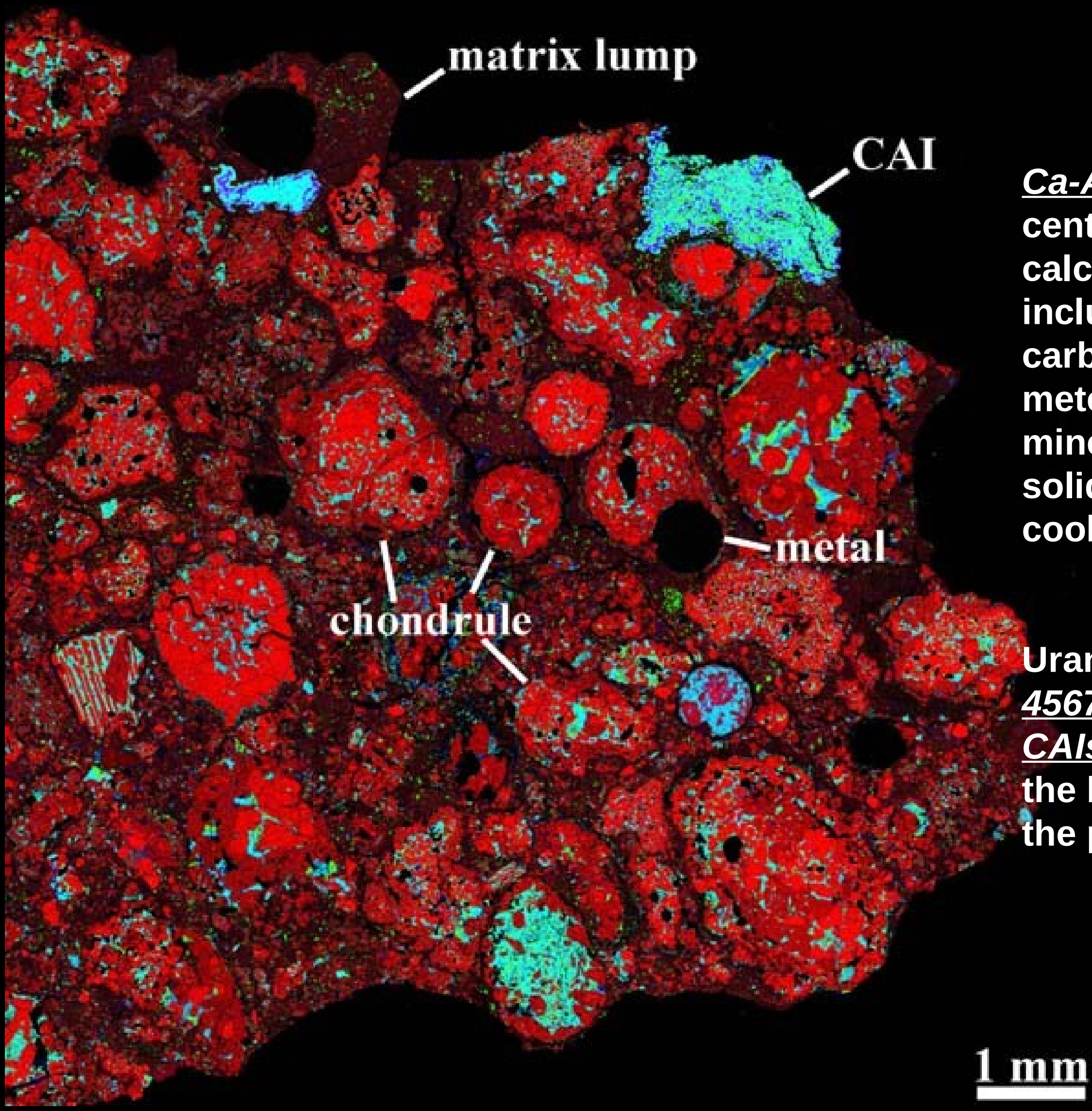


Solar Photosphere
Carbonaceous chondrites
10
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
O
C
N
Fe
Mg
S
Na
Al
Ni
Ca
Cr
Mn
P
K
Co
Ti
Zn
Cu
Ge
Sr
Sc
Rb
B
Y
Ba
Pb
Ce
Pr
Be
La
Li
Tm
Th
10⁻⁸ 10⁻⁷ 10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 1 10

Meteoritos:

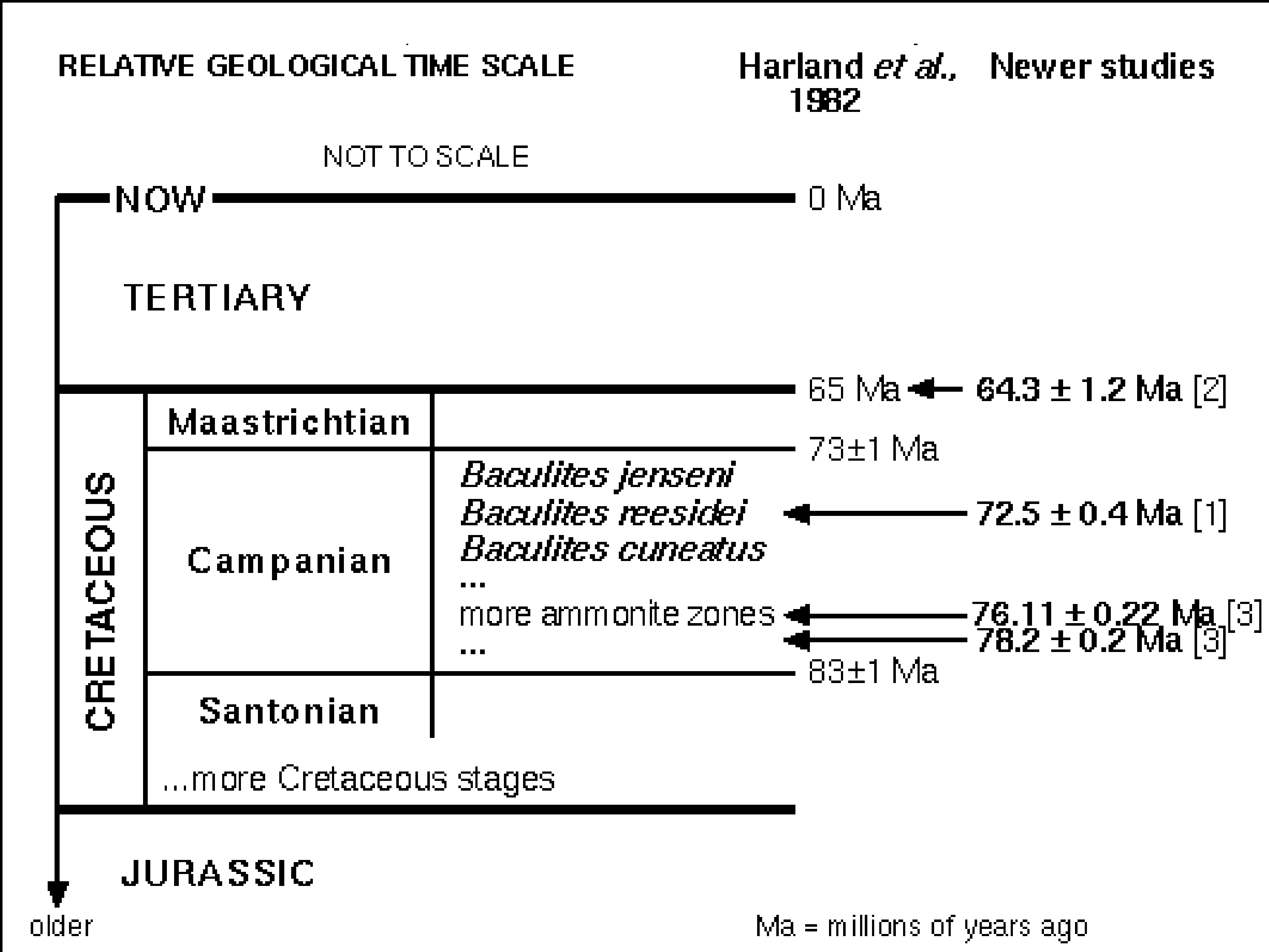
Edad de Formación del Sistema Solar





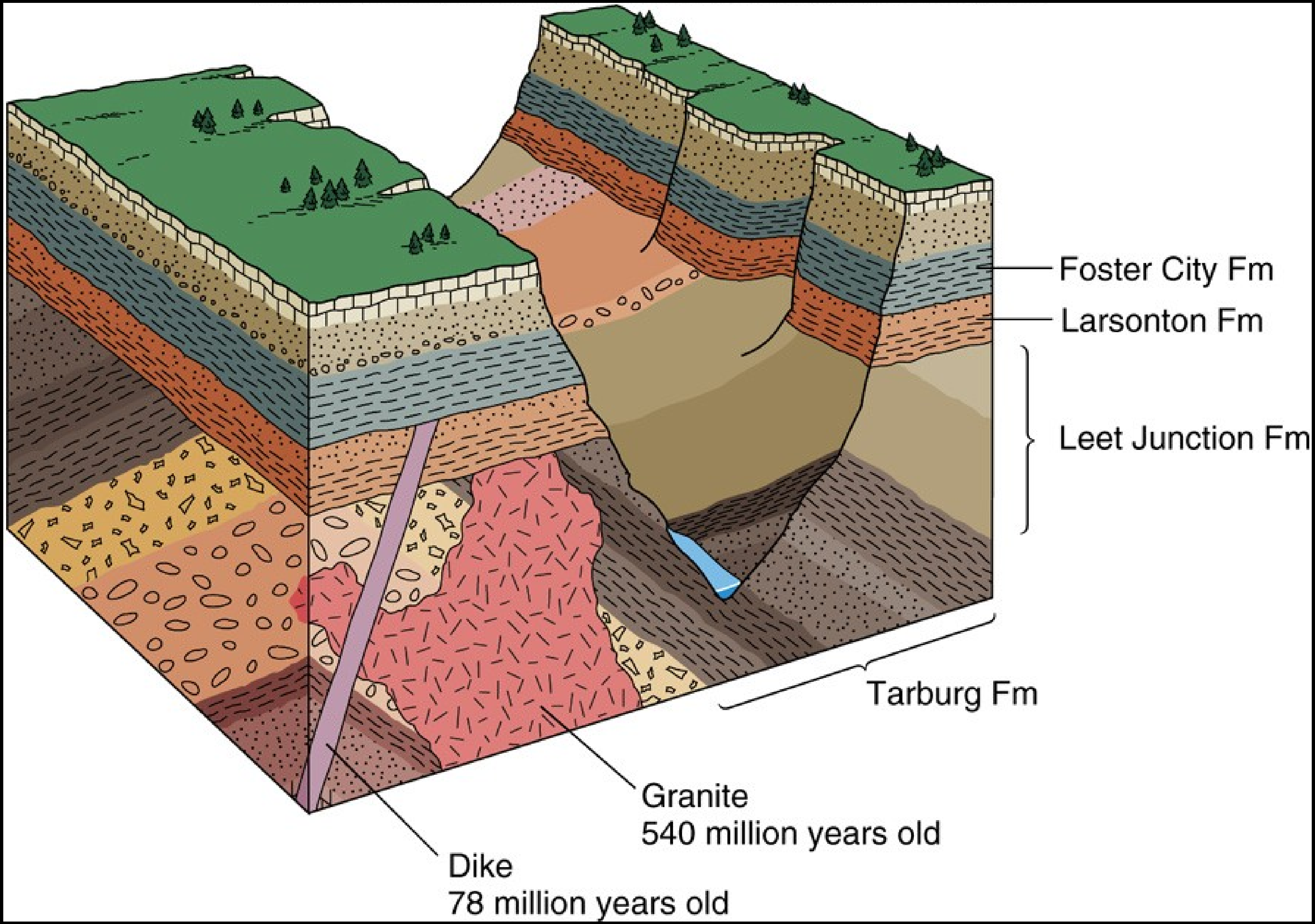
Ca-Al-rich inclusion (CAI) **are centimeter-sized light-colored calcium- and aluminium-rich inclusions found in carbonaceous chondrite meteorites. CAIs consist of minerals that are among the first solids condensed from the cooling protoplanetary disk.**

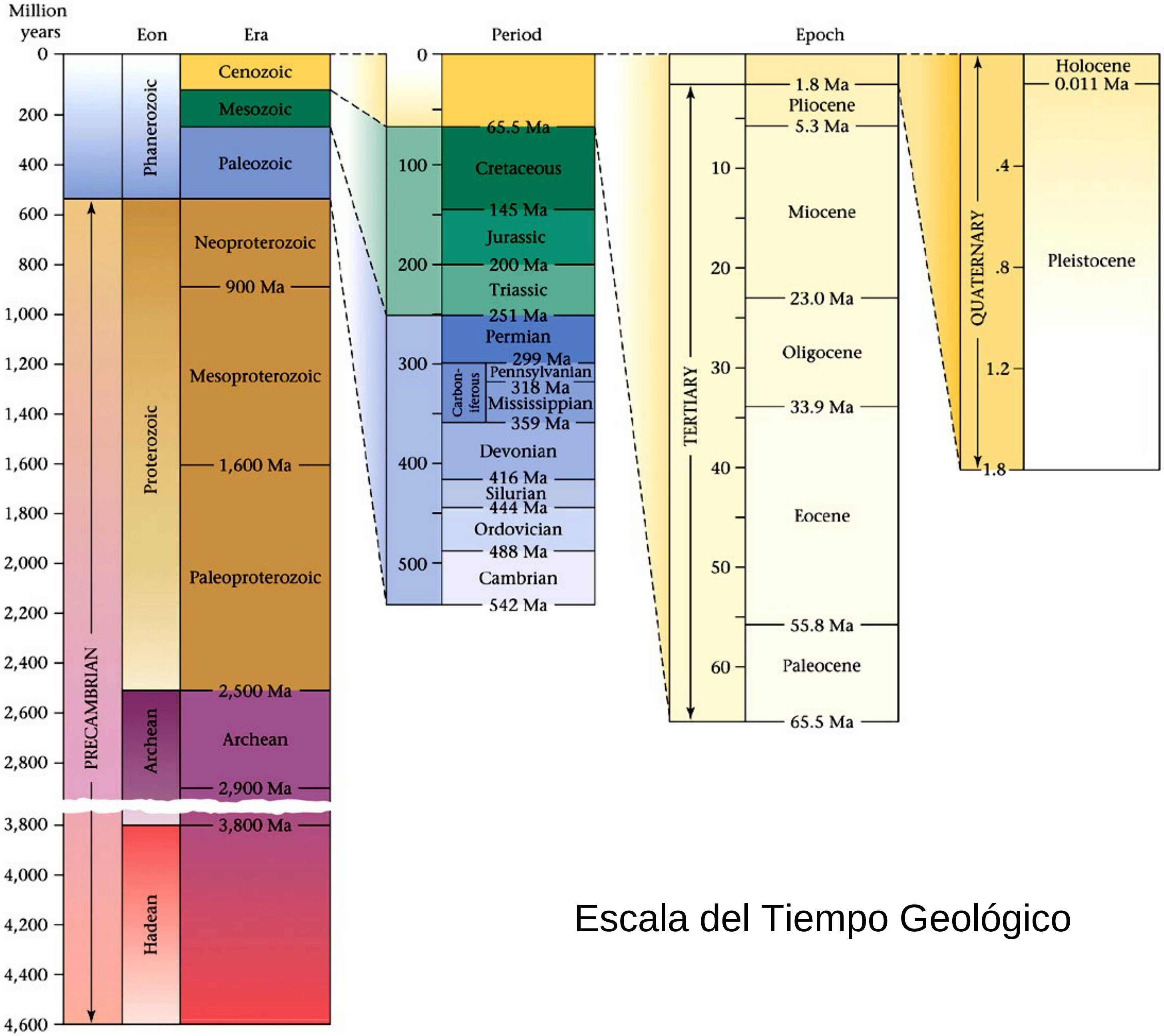
Uranium/lead isotopic ***ages of 4567.2±0.6 Ga determined on CAIs*****, has been interpreted as the beginning of the formation of the planetary system**



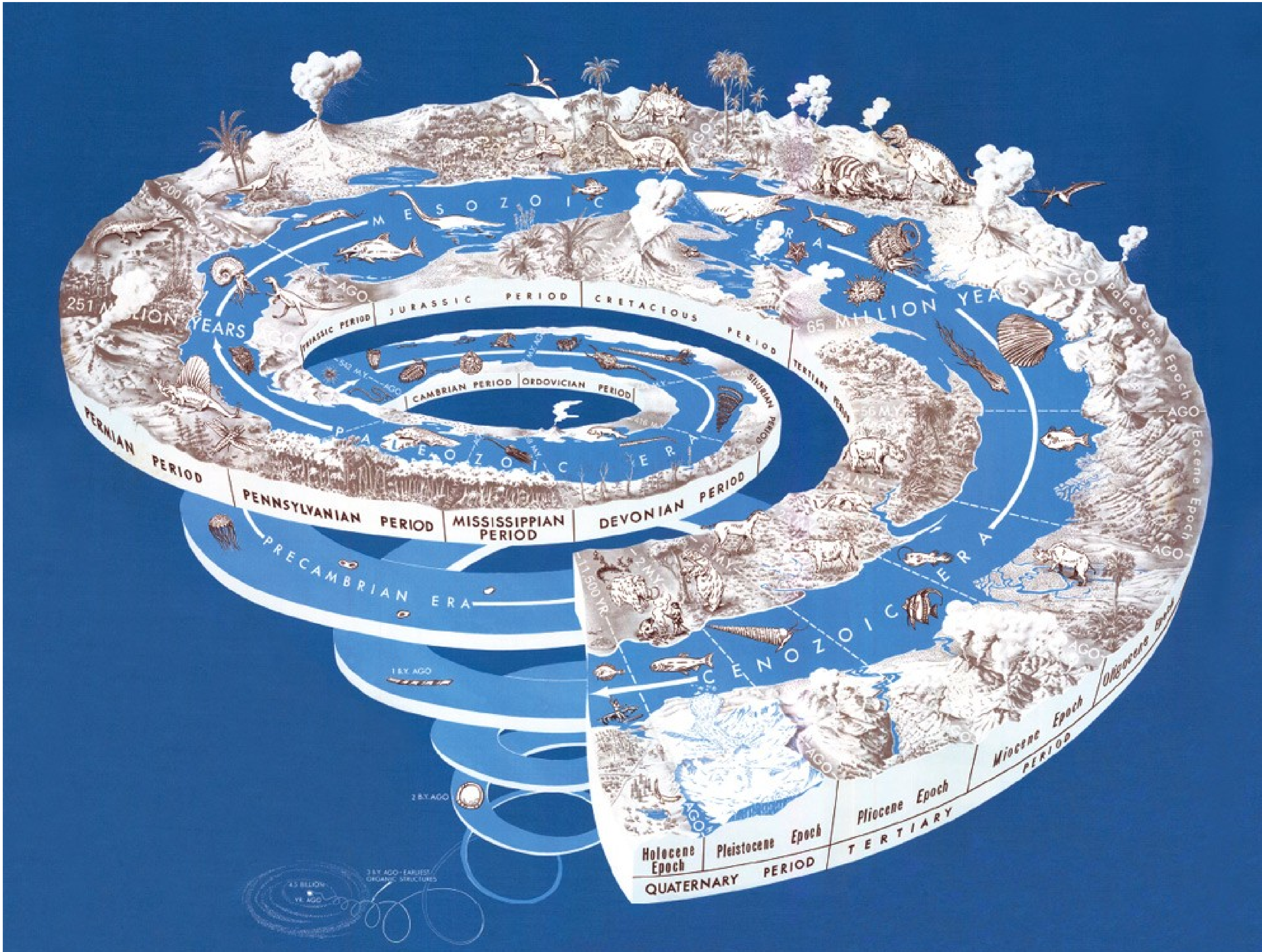
RELATIVE GEOLOGICAL TIME SCALE
Harland et al., 1982
Newer studies
NOT TO SCALE
NOW
0 Ma
TERTIARY
65 Ma
64.3 ± 1.2 Ma [2]
CRETACEOUS
Maastrichtian
73±1 Ma
Campanian
Baculites jenseni
Baculites reesidei
Baculites cuneatus
...
more ammonite zones
...
72.5 ± 0.4 Ma [1]
76.11 ± 0.22 Ma [3]
78.2 ± 0.2 Ma [3]
83±1 Ma
Santonian
...more Cretaceous stages
JURASSIC
older
Ma = millions of years ago

Relative And Absolute Dates Combined

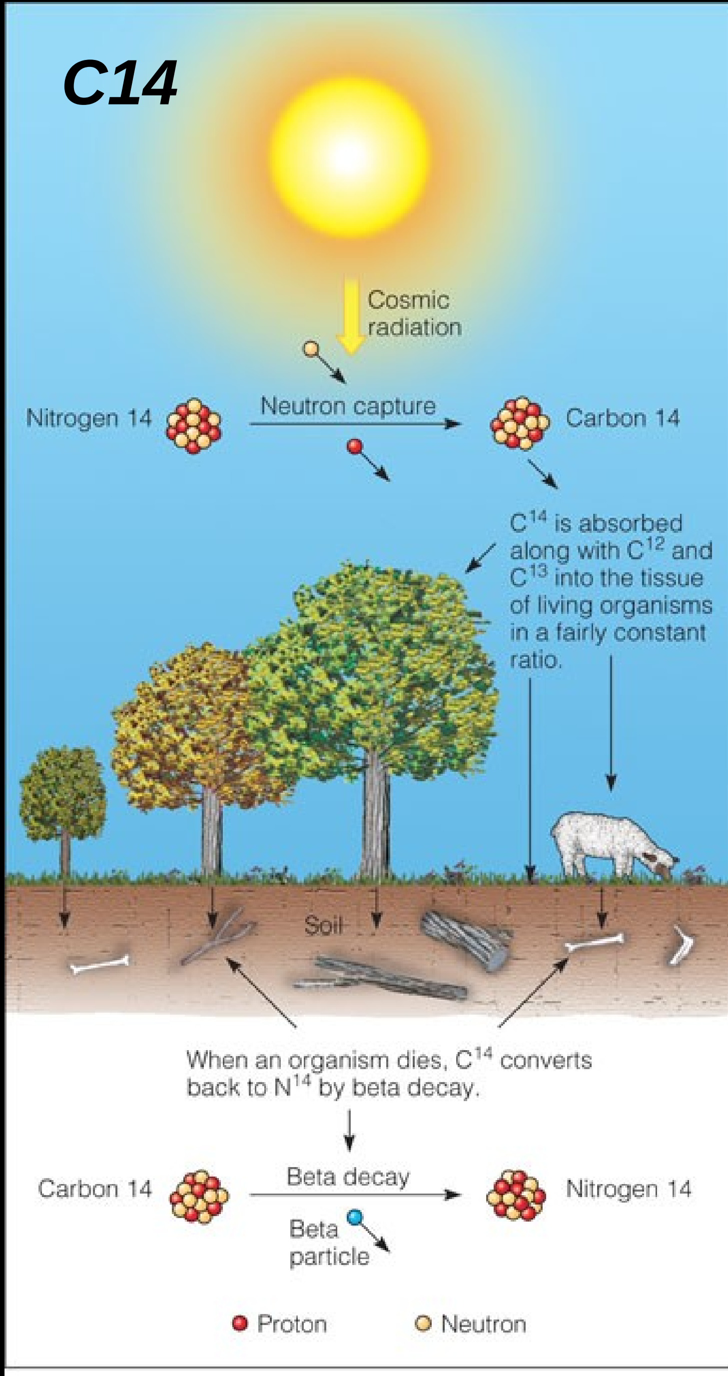




Escala del Tiempo Geológico



MESOZOIC ERA
251 MILLION YEARS AGO
200 M.Y.
TRIASSIC PERIOD
JURASSIC PERIOD
CRETACEOUS PERIOD
65 MILLION YEARS AGO
TERTIARY PERIOD
Paleocene Epoch
Eocene Epoch
Oligocene Epoch
Miocene Epoch
Pliocene Epoch
Pleistocene Epoch
Holocene Epoch
QUATERNARY PERIOD
TERTIARY PERIOD
CENOZOIC ERA
542 M.Y. AGO
CAMBRIAN PERIOD
ORDOVICIAN PERIOD
SILURIAN PERIOD
PALEOZOIC ERA
PERMIAN PERIOD
PENNSYLVANIAN PERIOD
MISSISSIPPIAN PERIOD
DEVONIAN PERIOD
PRECAMBRIAN ERA
1 B.Y. AGO
2 B.Y. AGO
3 B.Y. AGO - EARLIEST ORGANIC STRUCTURES
4.5 BILLION YR. AGO



Radiocarbon is first produced in the atmosphere by collisions of neutrons with nitrogen atoms (Nitrogen has 7 protons and 7 neutrons in its nucleus).

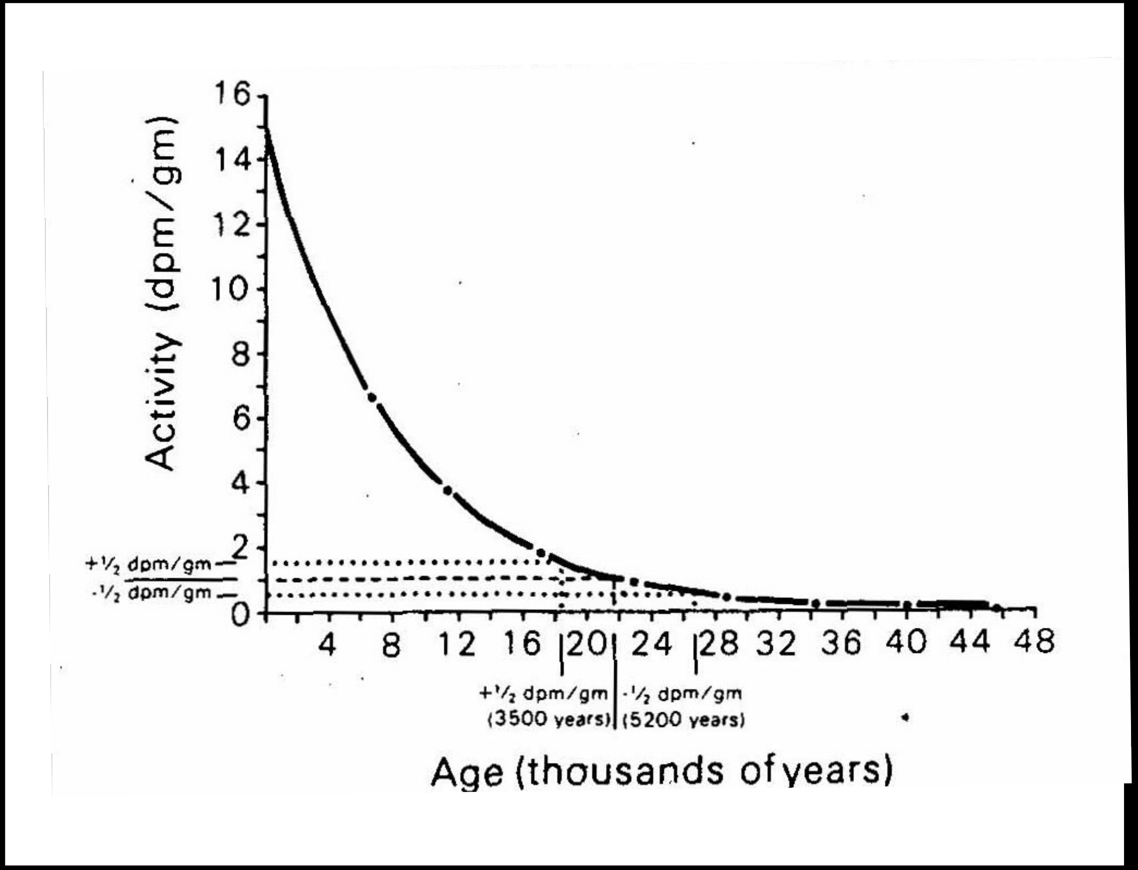
The neutron will knock out a proton from the nitrogen atom's nucleus, replacing it with a neutron. The proton number is reduced by 1 (it is now 6), but the mass number remains the same (14).

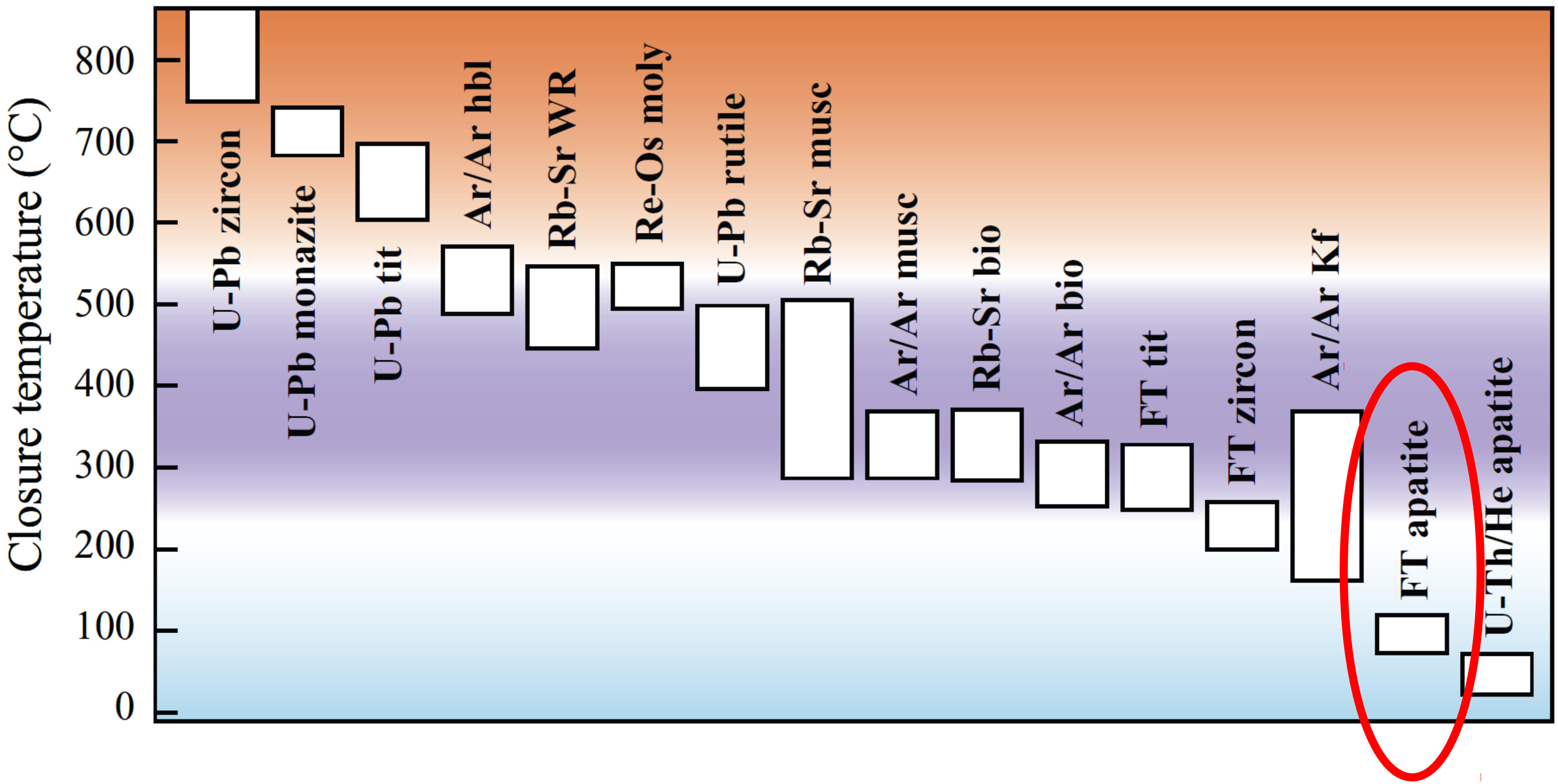
The atom will now have 6 protons and 8 neutrons in its nucleus and form the isotope ^{14}C (radiocarbon). C-14 is radioactive and decays with a half-life of 5730 years back to Nitrogen (^{14}N).

The ^{14}C atoms rapidly form CO_2 gas and then exchanged between the atmosphere, hydrosphere and biosphere. As long as the organism is alive it will continually exchange carbon within its reservoir and remain in equilibrium as new carbon is replenished. After the organism dies the ^{14}C clock is set as the ratio of ^{14}C/stable carbon (^{12}C and ^{13}C) decreases as ^{14}C decays to ^{14}N.

Radiocarbon Decay Activity

^{14}C decays to ^{14}N as it emits a beta (β) particle. The decay activity (Beta emission rate) will decrease by 50% every half-life (5730 years). Radiocarbon ages can be determined for organic matter by counting β-emissions.





“Temperaturas de Cierre” para distintos métodos de datación de minerales

Apatite Fission Track Analysis (AFTA®)

K

Apatito: $Ca_5(PO_4)_3(F,Cl,OH)$