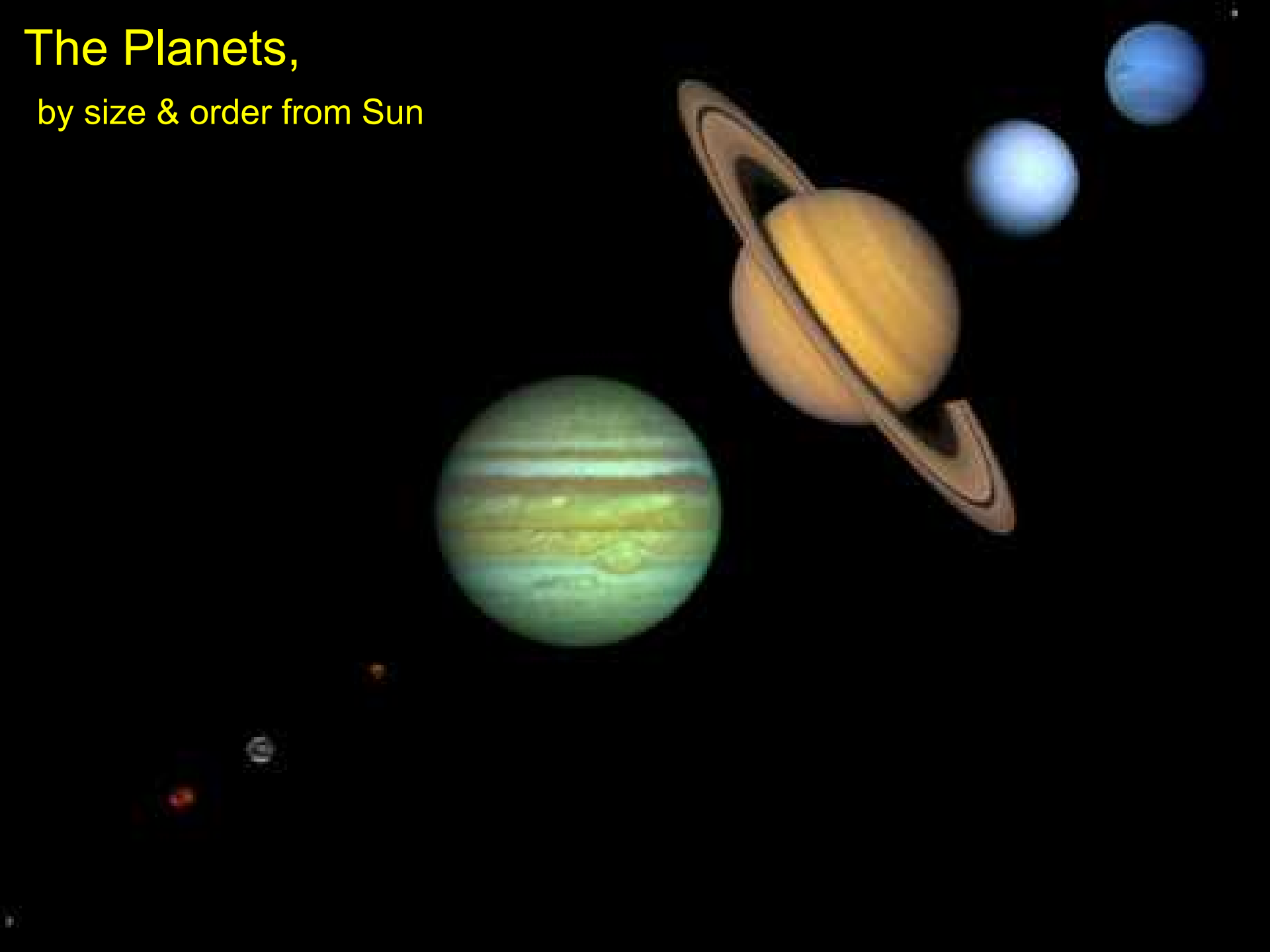
Planet Earth: Origin, Evolution, and Composition

Rahul Chopra

The Planets,

by size & order from Sun



The **Astronomical** Setting

The Earth orbits a star we call the Sun

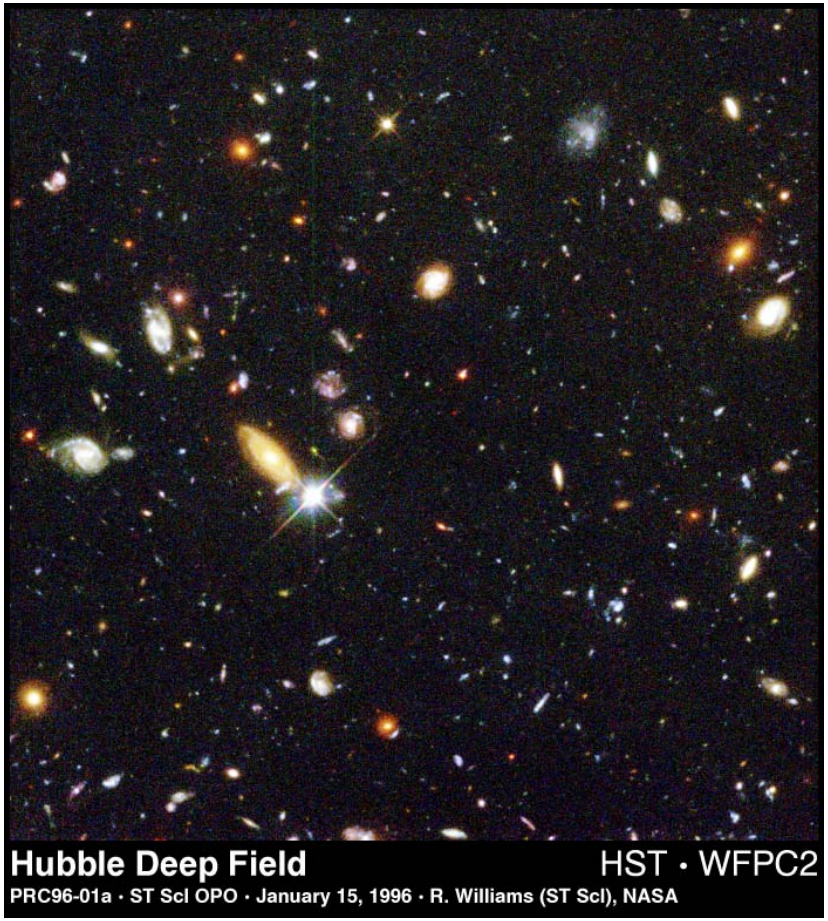
The Sun is one of a 100 billion stars in our galaxy (Milky Way)

(whirlpool galaxy)

~ 100000000000 stars

~ 10^{11} stars

Hubble Deep Field



100 billion galaxies within range of telescopes

So Many Stars

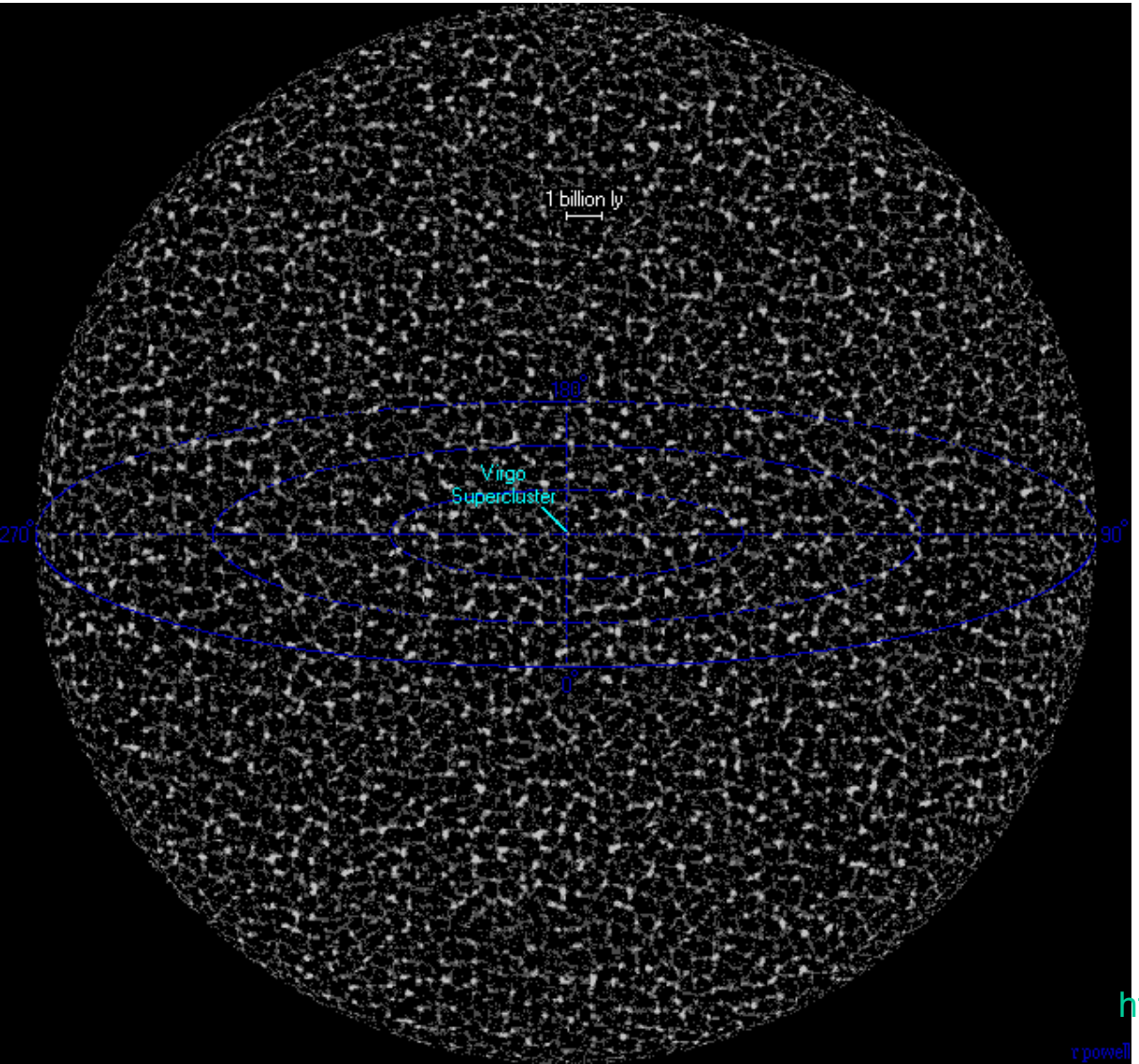
- 100 billion stars in a galaxy
- 100 billion galaxies with range of telescopes
- 10,000 billion billion stars

→ 100000000000000000000000 stars = 10^{22} stars

Could we really be alone in the Universe?

The visible universe, 14 billion light years across

Each bright spot is a cluster of galaxies



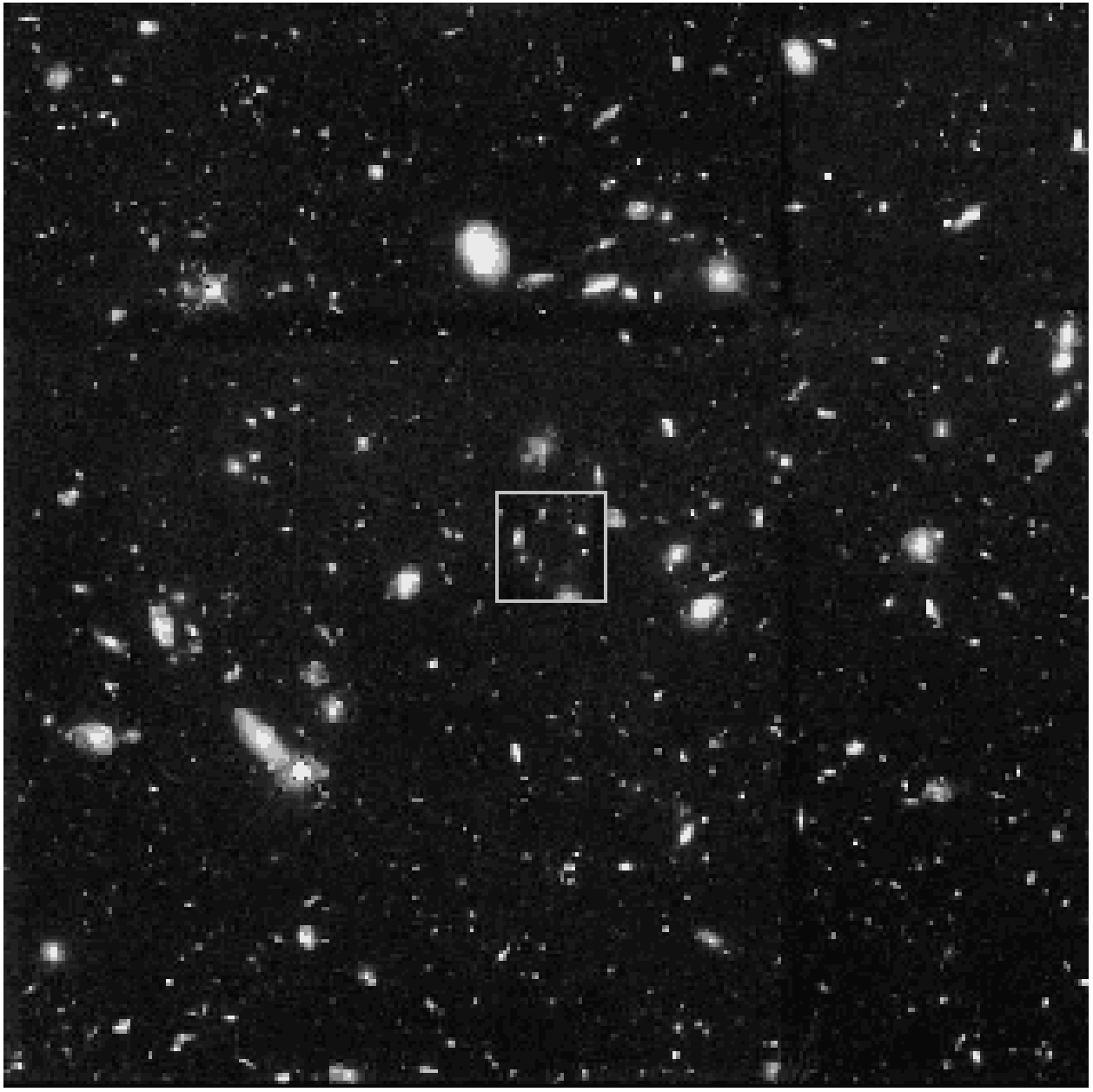
Note:

1 billion light-years = 10^9 ly

= about 10^{25} to 10^{26} m

http://www.atlasoftheuniverse.com

~10^{24} meters



~200,000,000 light years from Earth

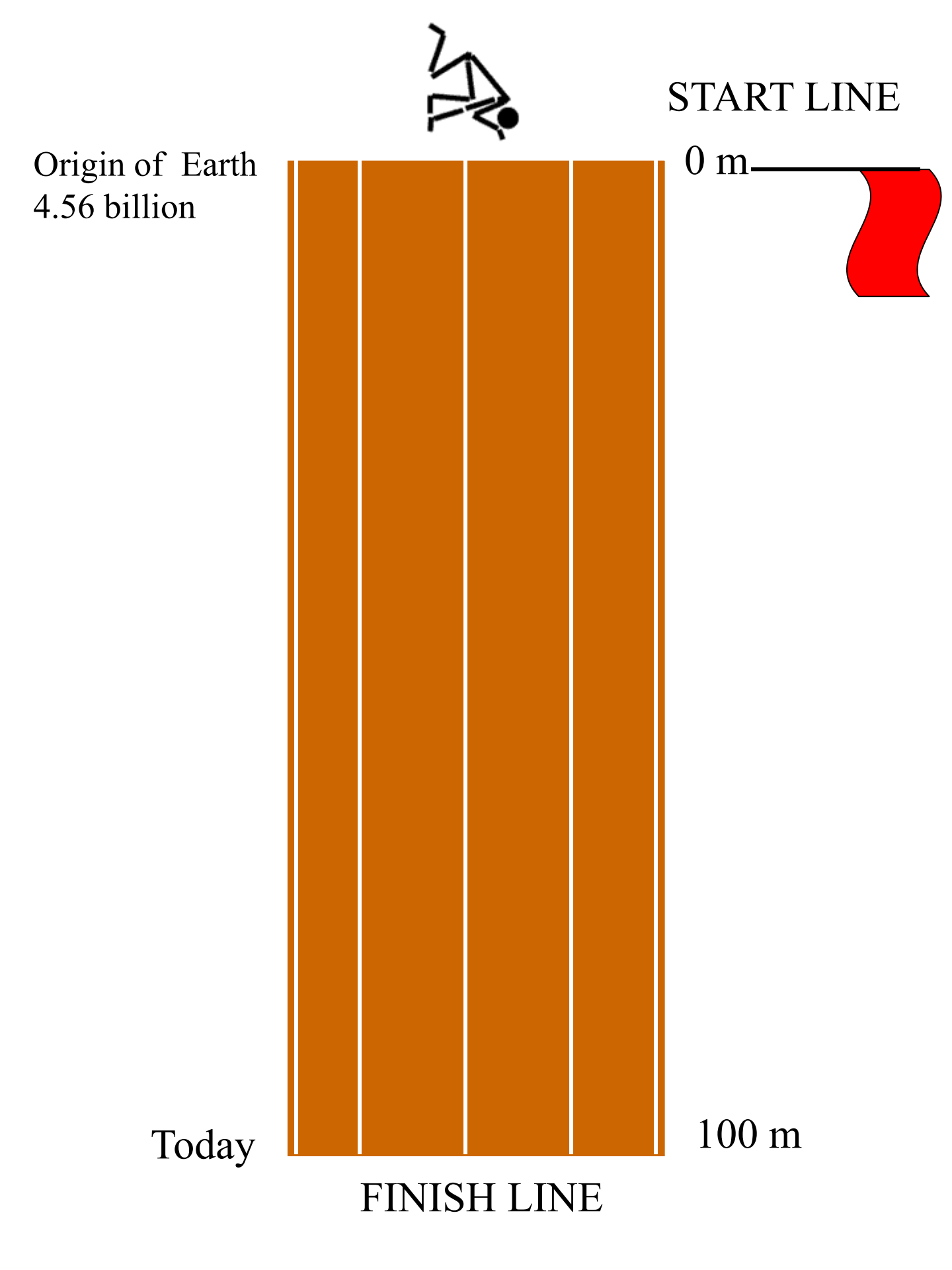
Galaxies are gravitationally bound into clusters containing hundreds or thousands of members.

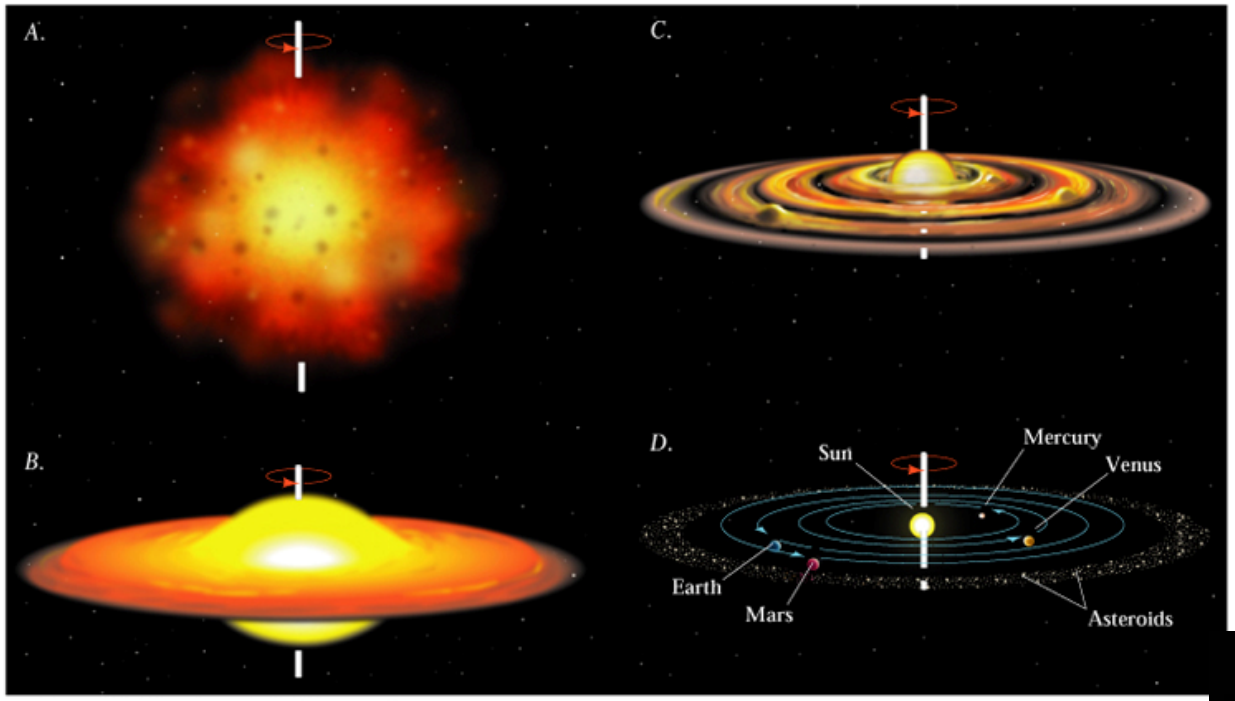
the Virgo Cluster, the home of our own Milky Way galaxy, is still invisible at the center of the image.

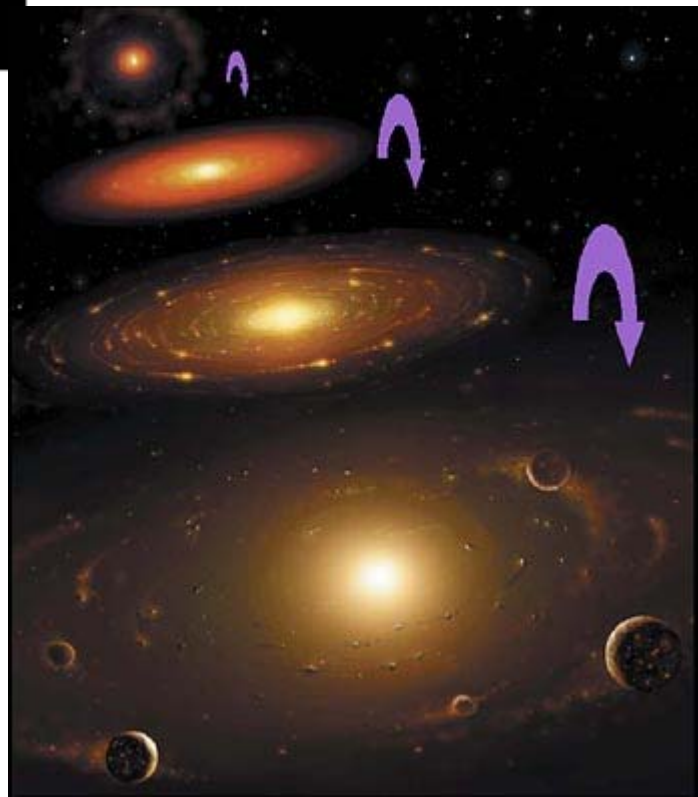
10^{21} m

Drawing of the Milky Way seen from above

Sun

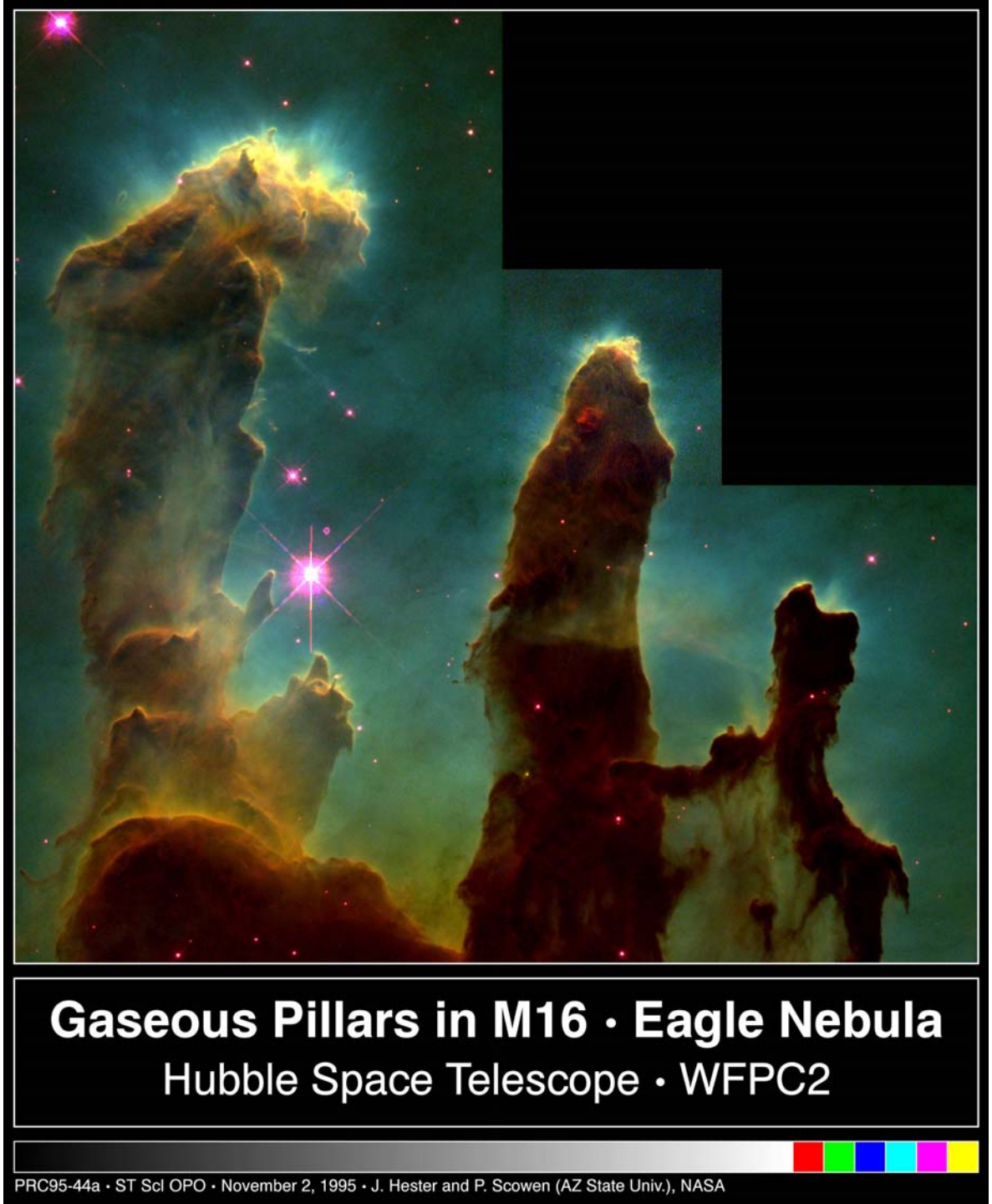

START LINE
0 m
Origin of Earth
4.56 billion
Today
100 m
FINISH LINE





Star-forming region

Clouds of gas and dust



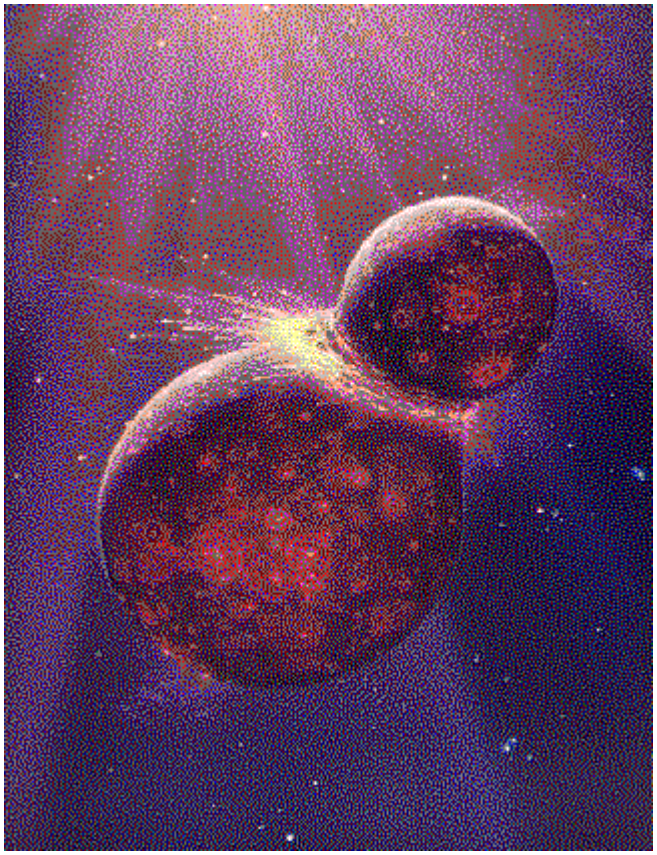
Origin of the Moon
4.5 billion years ago

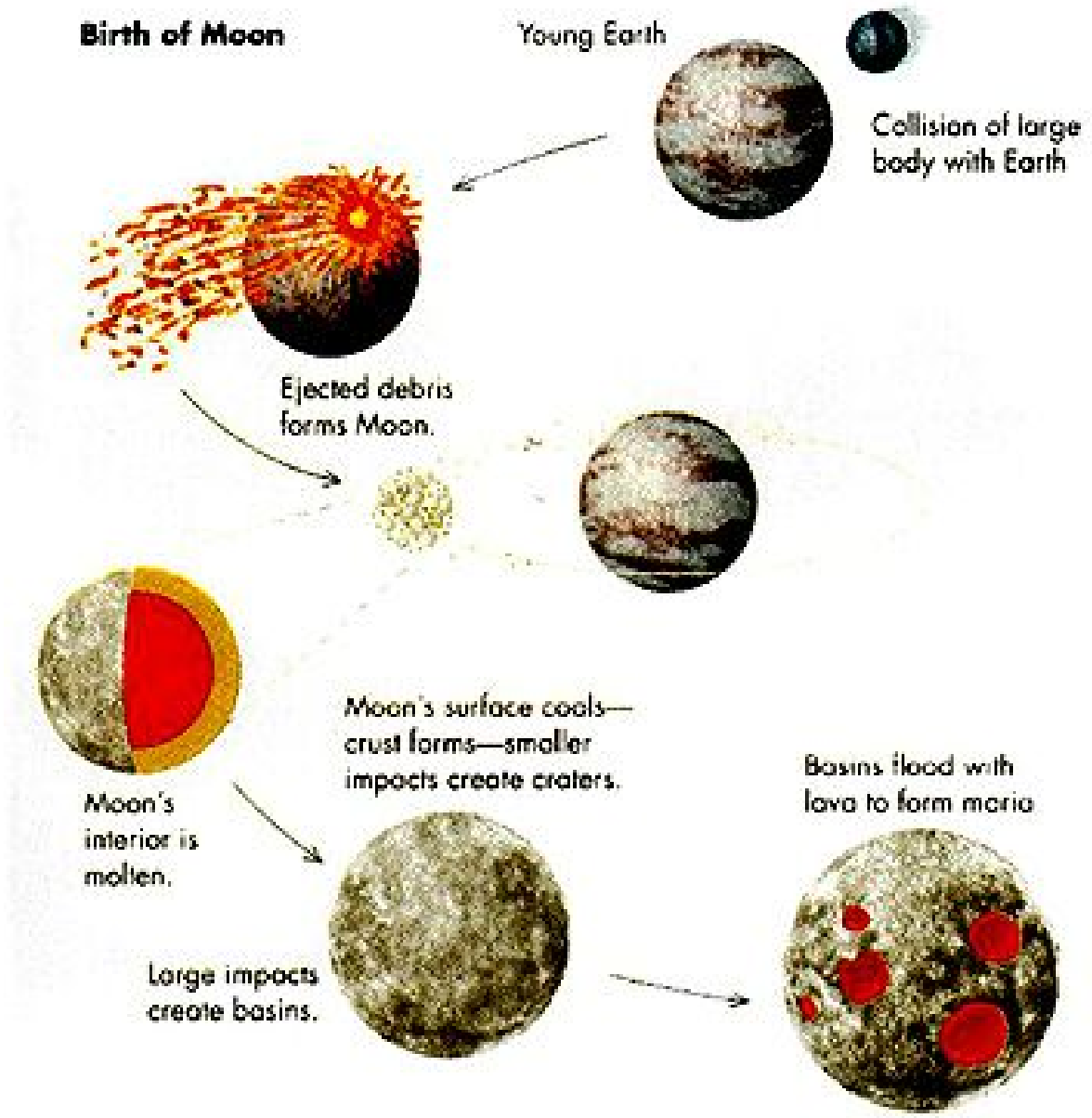
1.3 m

100 m

Today

FINISH LINE




Birth of Moon
Young Earth
Collision of large body with Earth
Ejected debris forms Moon.
Moon's interior is molten.
Moon's surface cools—crust forms—smaller impacts create craters.
Large impacts create basins.
Basins flood with lava to form maria

Origin of Earth

START LINE

Origin of Moon

4.5 billion

1.3 m

14.4 m

Oldest Rock

3.9 billion

Today

100 m

FINISH LINE

A rock from a banded iron formation in northern Quebec, Canada. The bands vary in thickness from approximately 10 microns (less than the width of a human hair), to 10 meters (30 feet). This sample is measures a few inches across. At 3.75 billion years of age, it is one of the oldest rocks on Earth. "These rocks, with meteorites, are the only time travel machines into the early history of our planet," said University of Chicago geoscientist Nicolas Dauphas.

Acosta gneiss. At 4.05 billion years old this is one of the oldest rocks.

Origin of Earth

START LINE

Origin of Moon

4.5 billion

1.3 m

14.4 m

Oldest Rock

3.9 billion

23.2 m

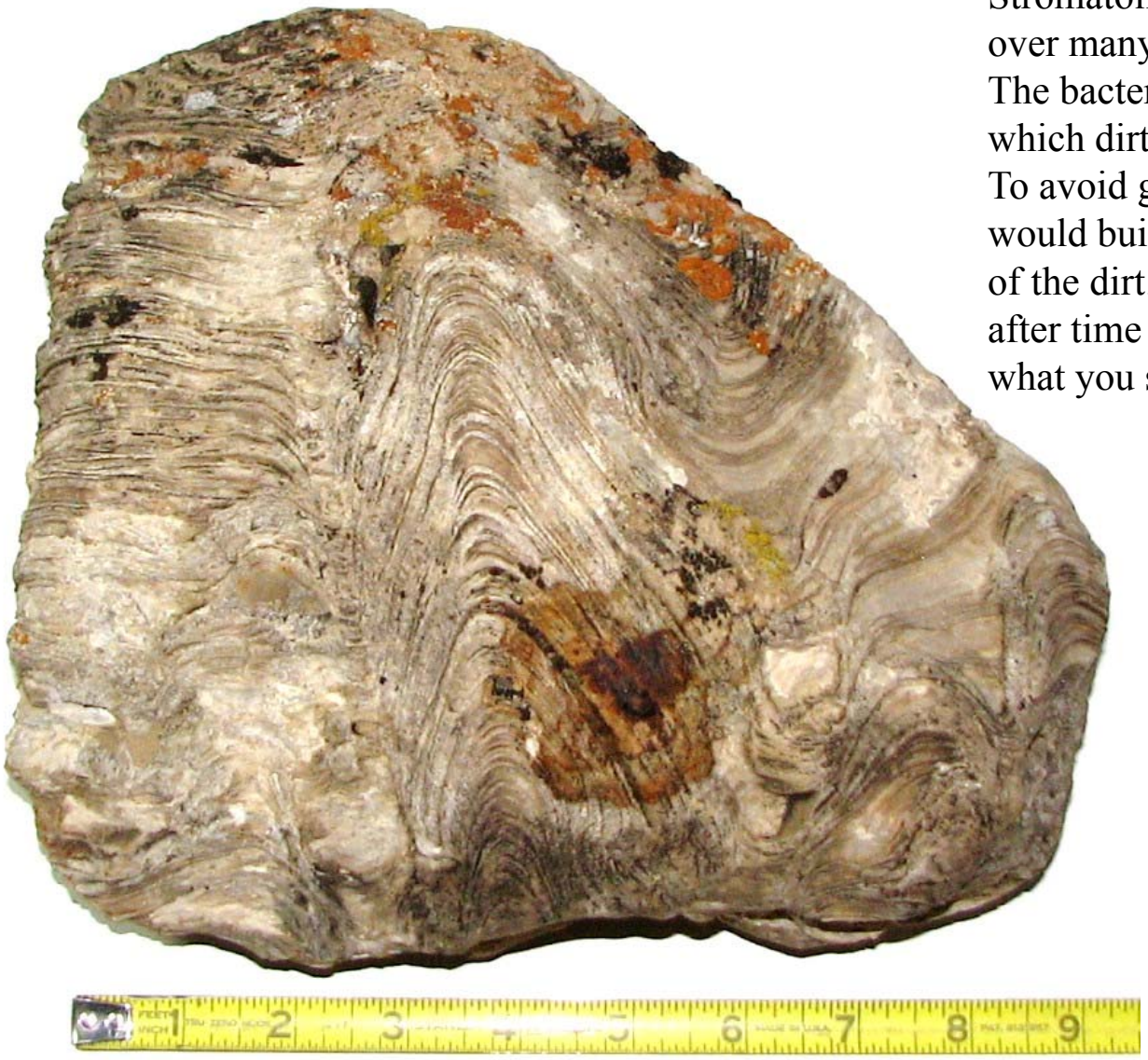
Oldest life

3.5 billion

Today

100 m

FINISH LINE



Stromatolite was built layer by layer over many years by Cyanobacteria. The bacteria would form a mat onto which dirt would fall.
To avoid getting buried, the bacteria would build a new colony, layer, on top of the dirt. This would happen time after time until a stromatolite similar to what you see above was formed.

Produced Oxygen

START LINE

Origin of Earth

Origin of Moon

4.5 billion

1.3 m

14.4 m

Oldest Rock

3.9 billion

23.2 m

Oldest life

3.5 billion

Oxygen

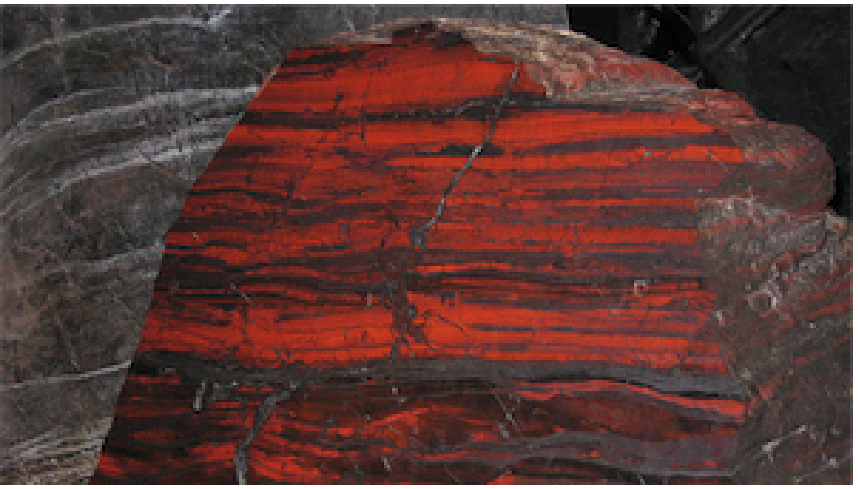
36.4 m

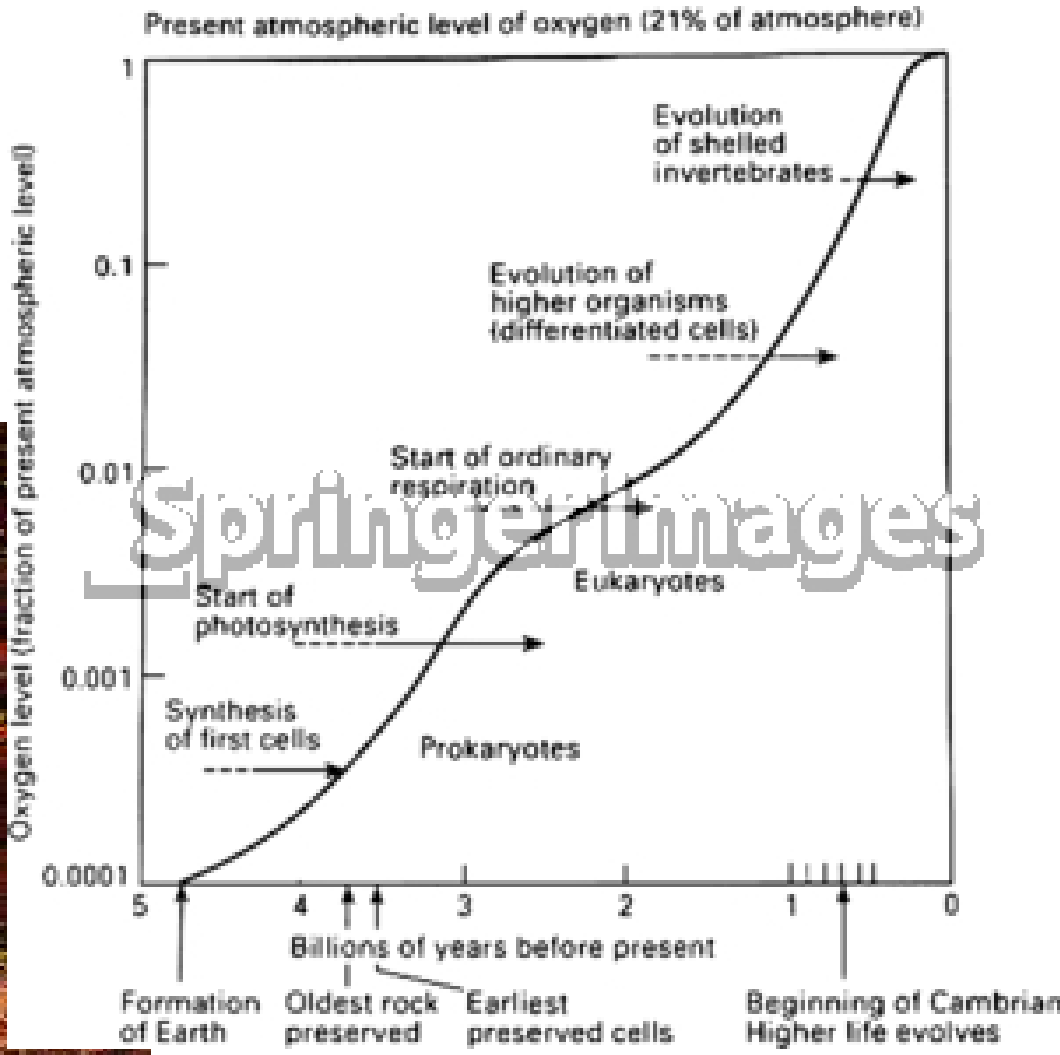
2.9 billion

Today

100 m

FINISH LINE





START LINE

Origin of Earth

Origin of Moon

4.5 billion

1.3 m

14.4 m

Oldest Rock

3.9 billion

23.2 m

Oldest life

3.5 billion

Oxygen

36.4 m

2.9 billion

87.9 m

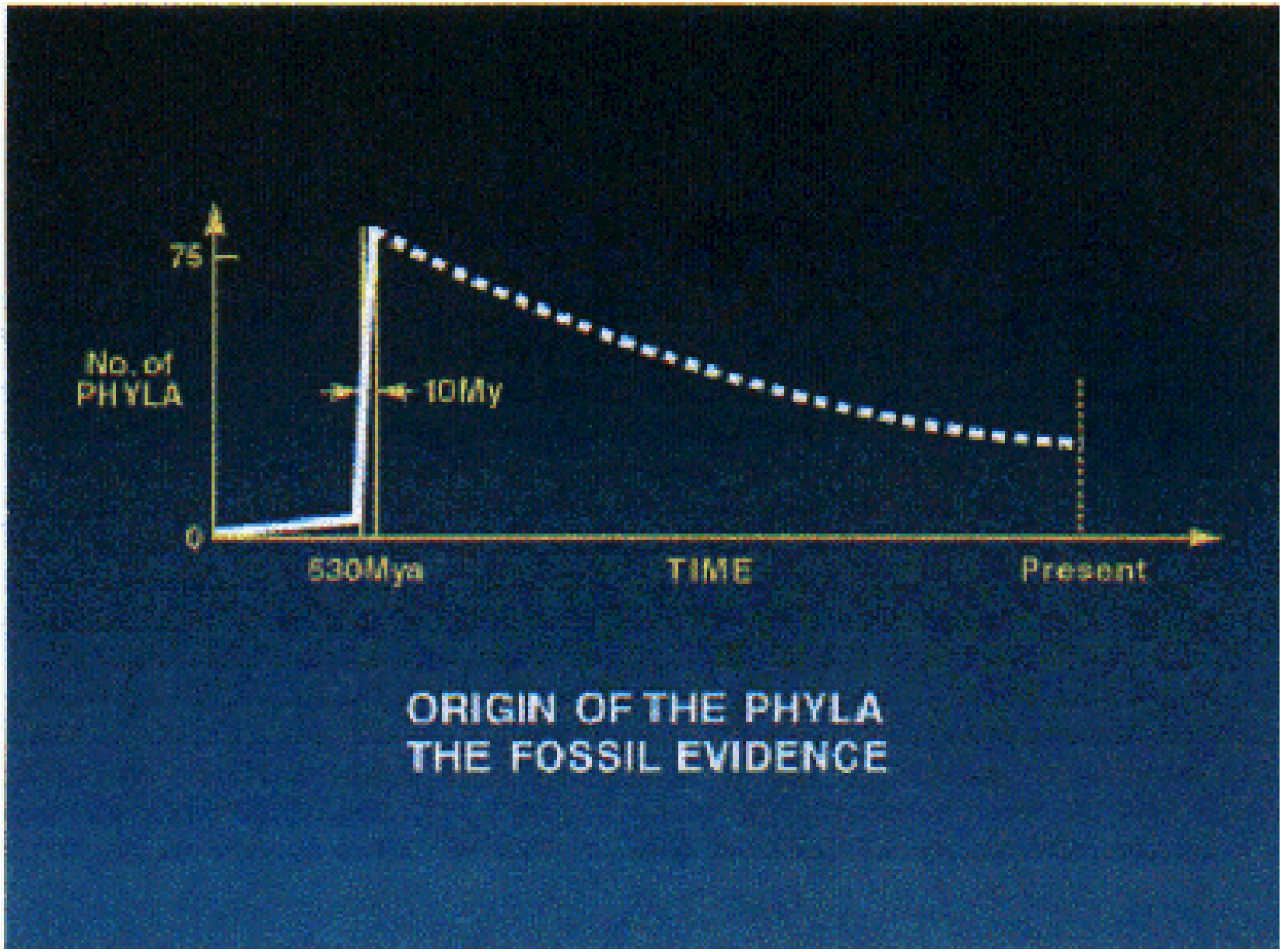
Cambrian Life

550 million

Today

100 m

FINISH LINE



ORIGIN OF THE PHYLA
THE FOSSIL EVIDENCE

START LINE

Origin of Earth

Origin of Moon

4.5 billion

1.3 m

Oldest Rock

3.9 billion

14.4 m

Oldest life

3.5 billion

23.2 m

Oxygen

2.9 billion

36.4 m

Cambrian Life

550 million

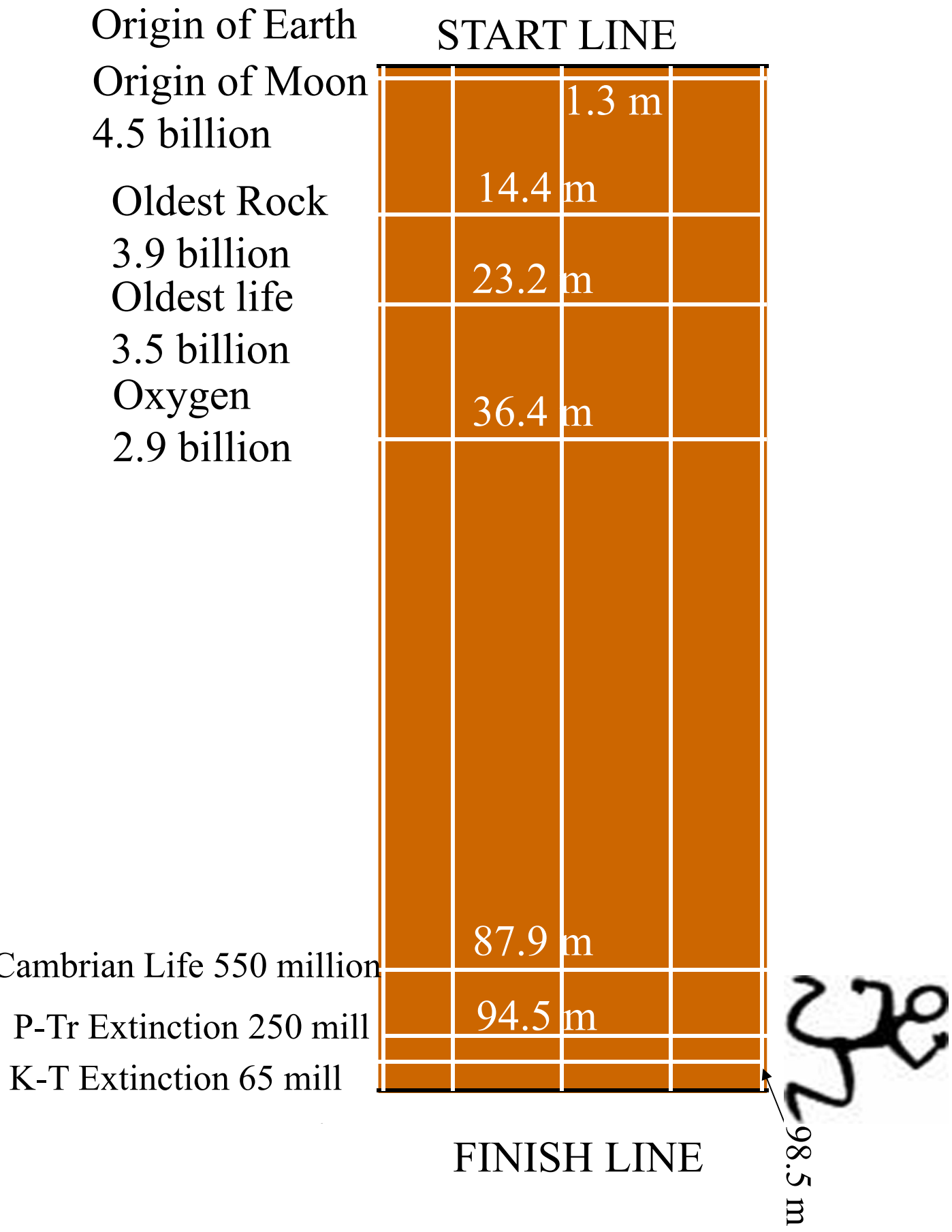
87.9 m

94.5 m

P-Tr Mass Extinction

250 million

FINISH LINE


Origin of Earth
START LINE
Origin of Moon
4.5 billion
1.3 m
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Oldest Rock
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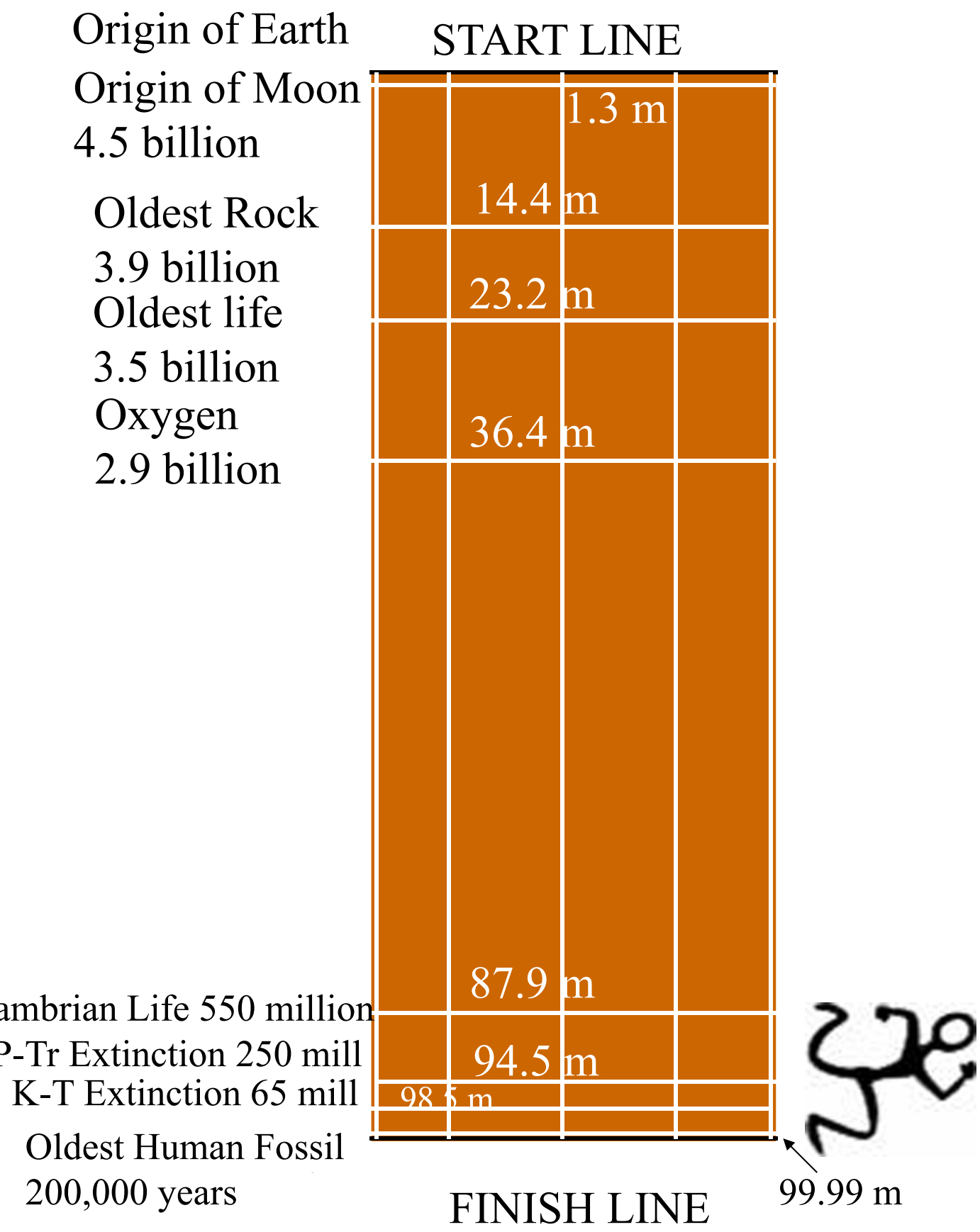
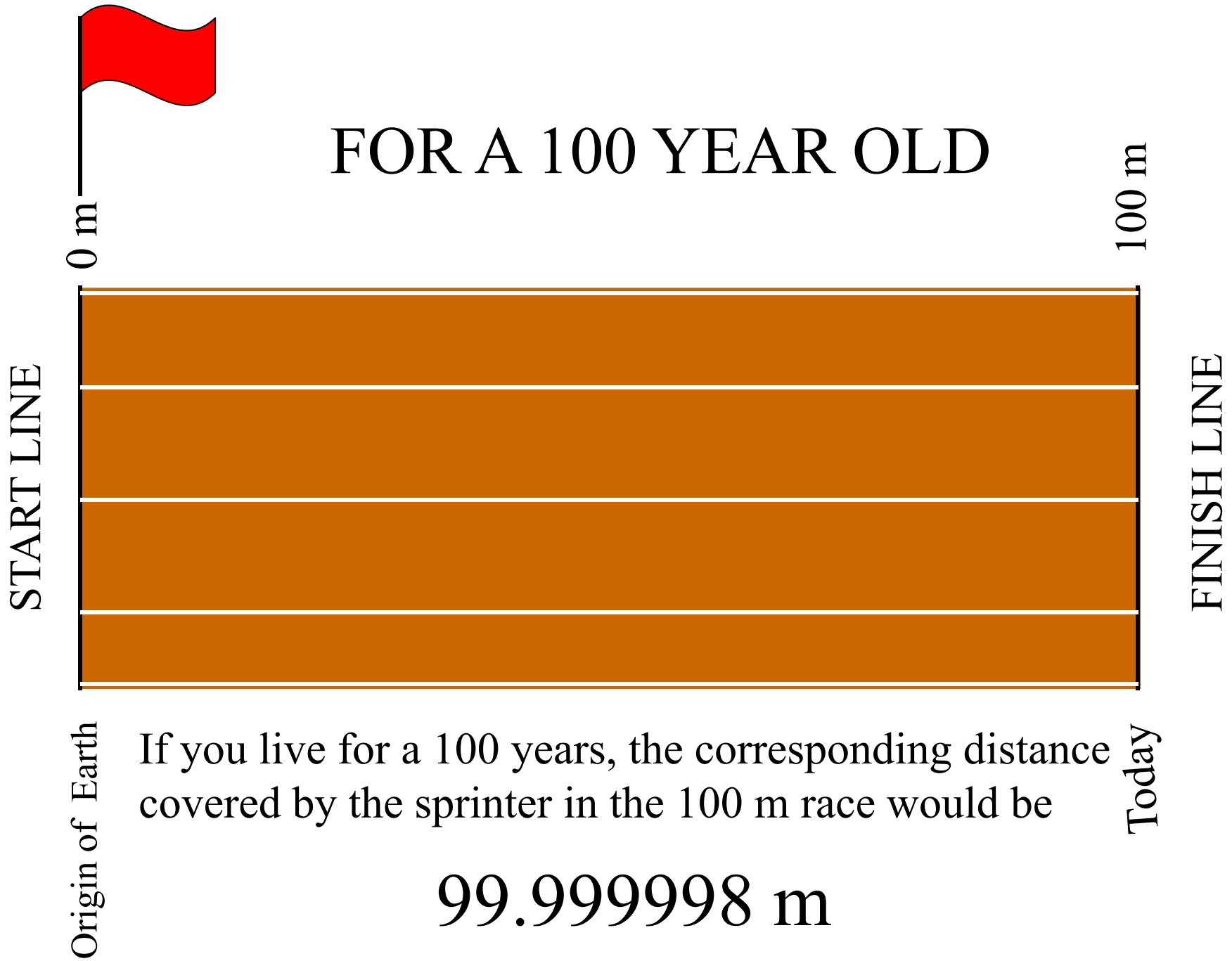
Oldest life
3.5 billion
Oxygen
2.9 billion
36.4 m
87.9 m
Cambrian Life 550 million
94.5 m
P-Tr Extinction 250 mill
K-T Extinction 65 mill
98.5 m
FINISH LINE


Origin of Earth
Origin of Moon
4.5 billion
START LINE
1.3 m
14.4 m
Oldest Rock
3.9 billion
23.2 m
Oldest life
3.5 billion
Oxygen
2.9 billion
36.4 m
87.9 m
ambrian Life 550 million
P-Tr Extinction 250 mill
94.5 m
K-T Extinction 65 mill
98.5 m
Oldest Human Fossil
200,000 years
99.99 m
FINISH LINE

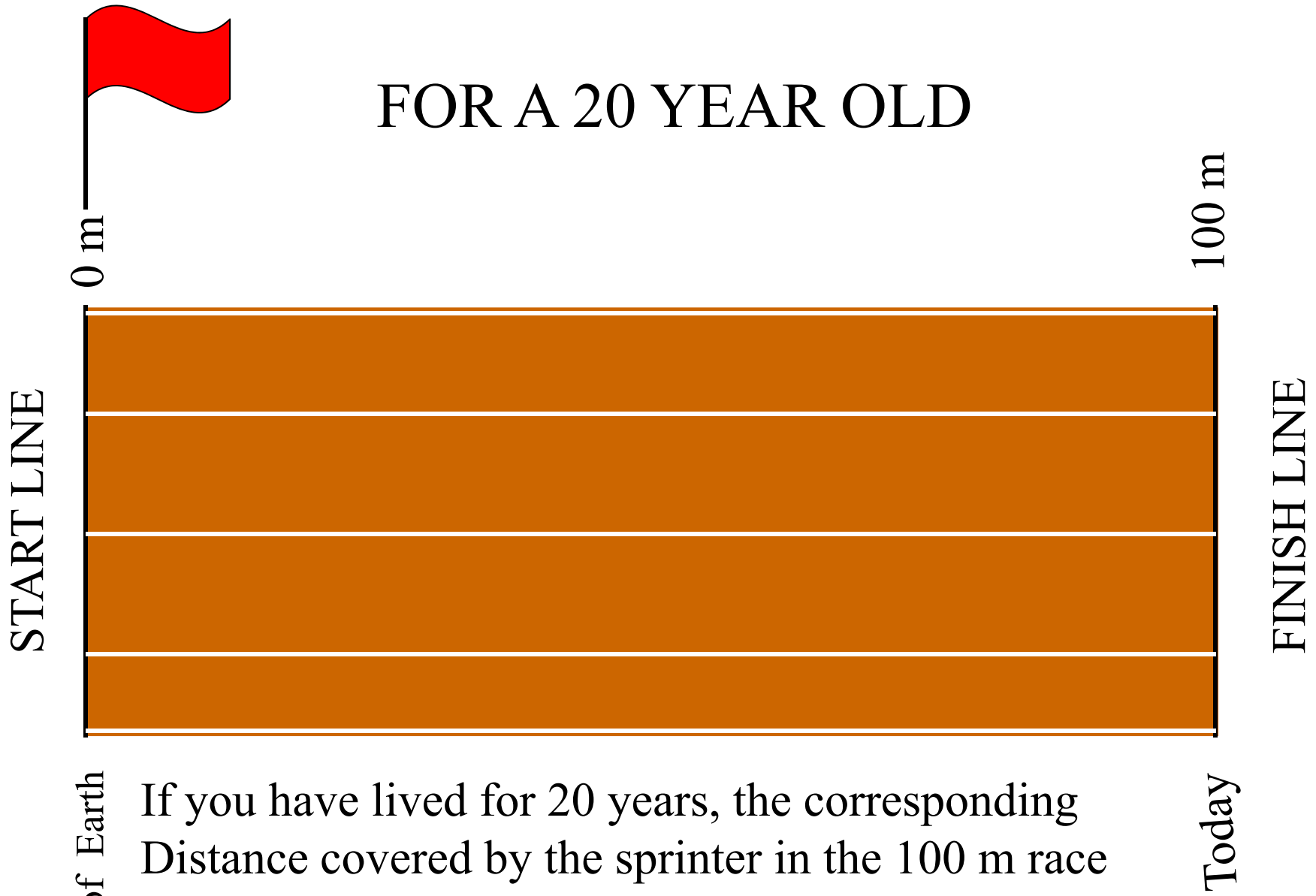
FOR A 100 YEAR OLD



If you live for a 100 years, the corresponding distance covered by the sprinter in the 100 m race would be

99.999998 m

FOR A 20 YEAR OLD



If you have lived for 20 years, the corresponding Distance covered by the sprinter in the 100 m race would be

99.9999996 m

A 100 year old human has spent 0.000002 % of geologic time on planet Earth

A 20 year old has spent 0.0000004 % of geologic time on planet Earth

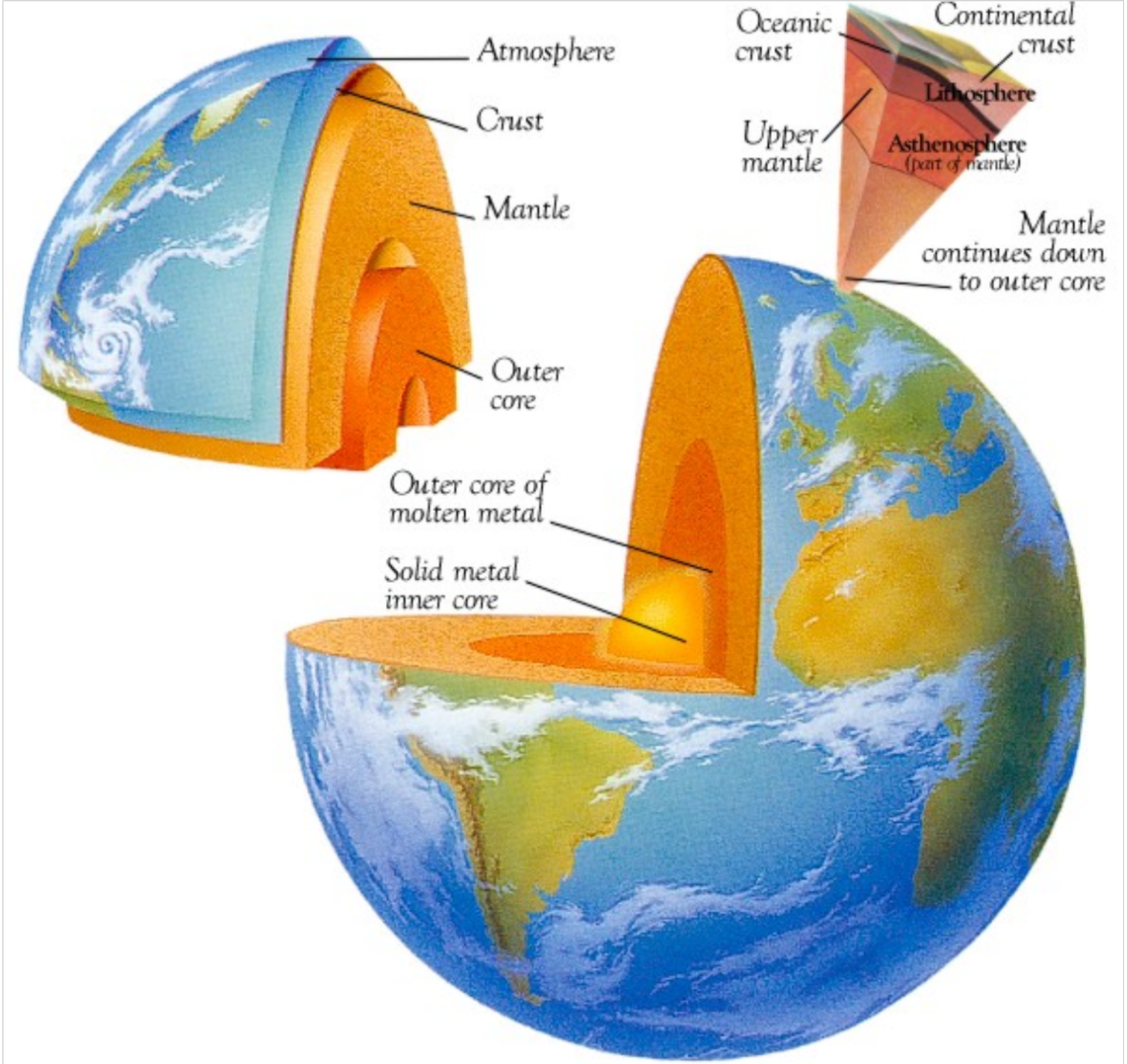
EARTH MATERIALS

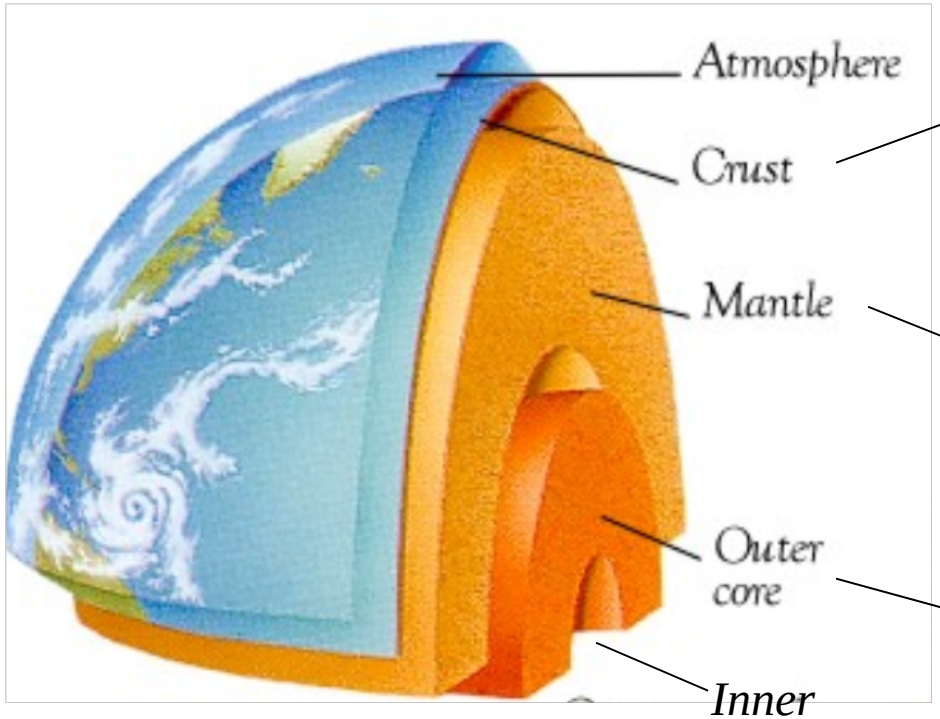
MINERALS

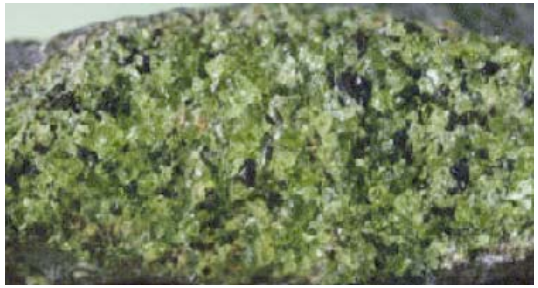
IGNEOUS ROCKS

SEDIMENTARY ROCKS

METAMORPHIC ROCKS


Atmosphere
Crust
Mantle
Outer core
Outer core of molten metal
Solid metal inner core
Oceanic crust
Continental crust
Lithosphere
Upper mantle
Asthenosphere
(part of mantle)
Mantle continues down to outer core





Liquid

Rock: A solid aggregate of one or more minerals.

Mineral: A naturally occurring, solid, element or compound with a definite composition or a range of compositions, usually possessing a regular internal crystalline structure.

Crystal: A form of matter in which atoms, ions, or molecules are arranged regularly in space to form a repeating network, the crystal faces are a reflection of this internal regularity.

Olivine

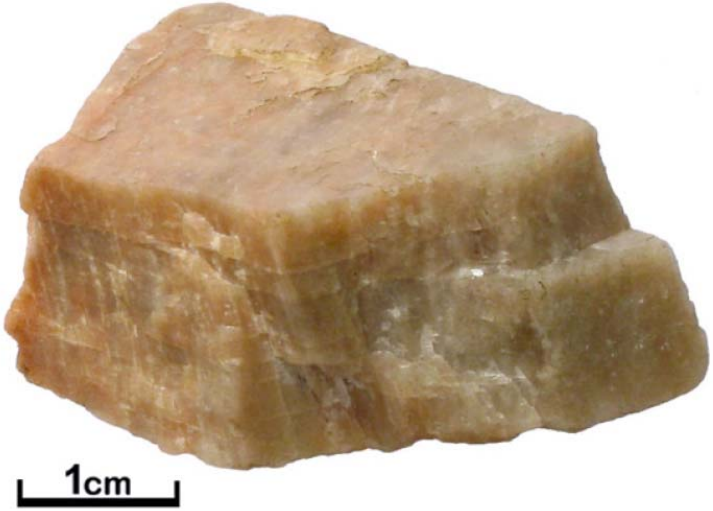
$(Mg,Fe)_2SiO_4$

Pyroxene

MgSiO3; FeSiO3; CaSiO3

$NaAlSi_3O_8$
Albite

Feldspars



$KAlSi_3O_8$
Potassium feldspar

Quartz SiO_2

Rocks:

Rocks are subdivided in terms of their origin:

1. **Igneous**: Rocks produced by the cooling and solidification of melts
   (i) **Extrusive** igneous rocks: Rapidly cooled by eruption of lavas on the surface or under water. Fine grained due to rapid cooling not allowing enough time for large crystals to grow. What we call volcanic rocks are typically extrusive igneous rocks.
   (ii) **Intrusive** igneous rocks: Produced by melts cooling and crystallizing within the Earth. The slower the cooling the larger the crystals produced.

2. **Sedimentary:** Rocks formed by the accumulation and cementation of mineral grains transported by wind, water, or ice; or by chemical precipitation.

3. **Metamorphic:** Rocks whose original composition, mineralogy, and/or appearance has been changed by high temperature and pressure.

IGNEOUS ROCKS:

TWO MAIN CLASSES:
1. INTRUSIVE OR PLUTONIC AND
2. EXTRUSIVE OR VOLCANIC

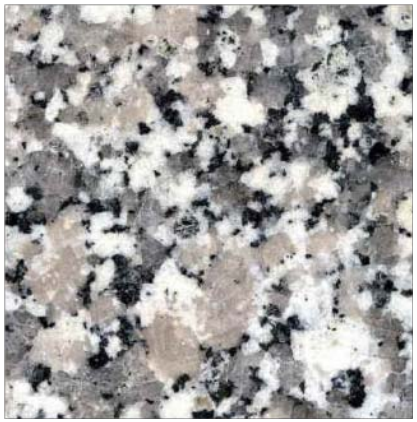
IGNEOUS ROCKS CLASSIFIED ON BASIS OF

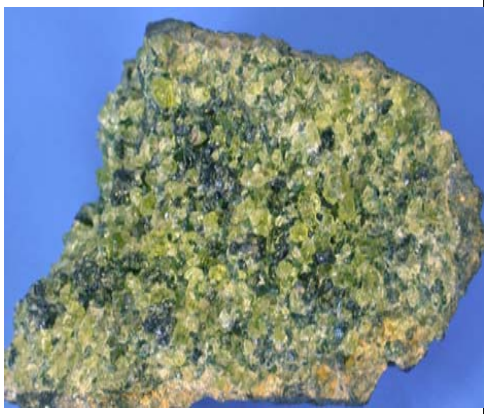
1. TEXTURE: COARSE GRAINED, FINE GRAINED, PORPHYRTITC. GLASSY, VESICULAR

AND

2. PROPORTION OF ROCK FORMING MINERALS

Texture					
	Aphanitic	Rhyolite	Andesite	Basalt	-rare-
	Phaneritic	Granite	Diorite	Gabbro	Peridotite
Composition		Felsic	Inter-mediate	Mafic	Ultra-mafic





GRANITE

DIORITE

GABBRO

PERIDOTITE

RHYOLITE

ANDESITE

BASALT

OBSIDIAN

PUMICE

Sedimentary Rocks

Sedimentary rocks are rocks that have been deposited by water, wind, or ice, either on land or under the sea. Sediment consists of loose grains, whereas a sedimentary rock consists of grains that have either been cemented together by chemical precipitates or been tightly compacted by the weight of overlying sediments.

Types of Sedimentary Rocks:

Sedimentary rocks may be:

Clastic: These are sedimentary rocks which have formed by the lithification of sediments derived from the erosion and break-up of other rocks.

Biogenic: These are sedimentary rocks composed of particles produced by organisms.

Chemical: These are sedimentary rocks composed of material derived from chemical processes such as precipitation of evaporated material from lakes, seas etc.

CLASSIFICATION OF CLASTIC SEDIMENTARY ROCKS

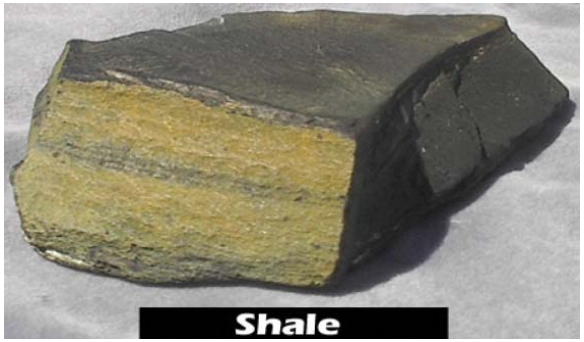
Size of Particle (mm)	Name of particle	Common Sedimentary Name	Name of Clastic Sedimentary Rock
> 256	Boulder	Gravel	Conglomerate or Breccia
64 – 256	Cobble	Gravel	Conglomerate or Breccia
4 – 64	Pebble	Gravel	Conglomerate or Breccia
2 – 4	Gravel	Gravel	Conglomerate or Breccia
1/16 – 2	Sand	Sand	Sandstone
< 1/16	Silt or clay	Mud	Shale

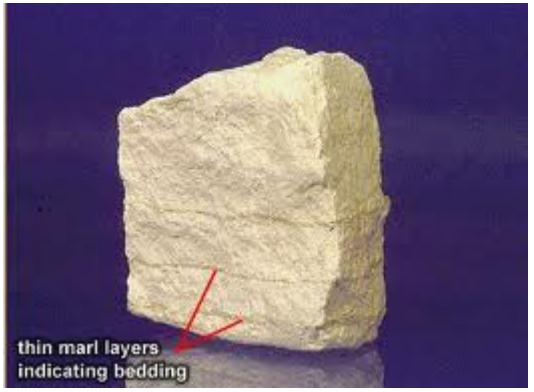
Conglomerate

Breccia

Sandstone

Coquina Limestone





Chalk Limestone

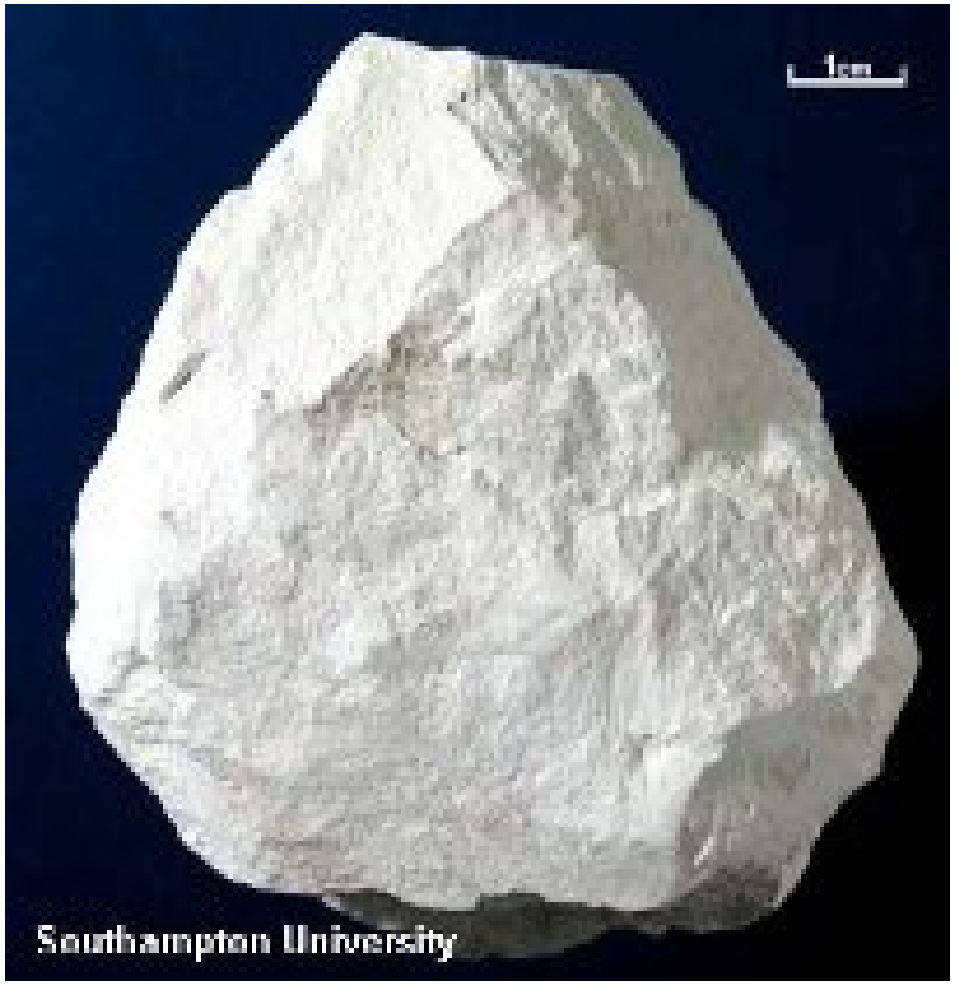
SEDIMENTARY ROCKS

BRECCIA

SANDSTONE

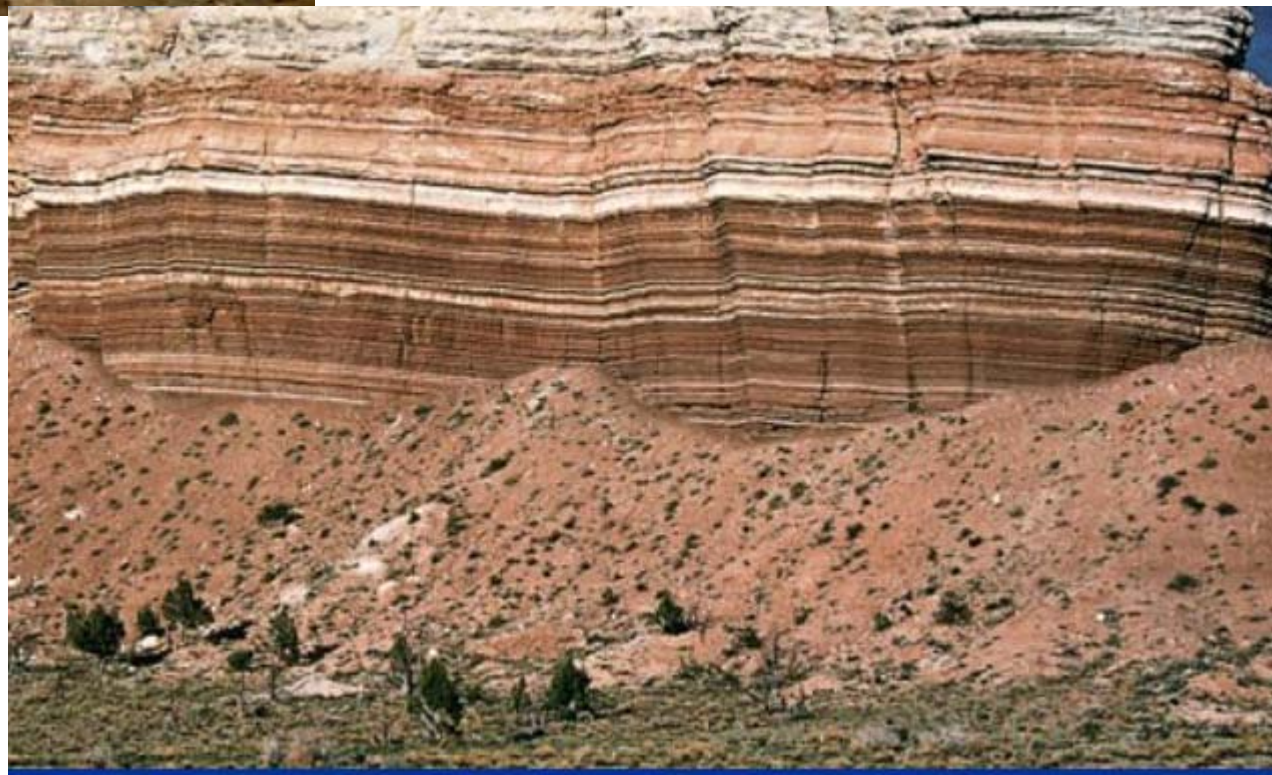
SHALE

COQUINA LIMESTONE

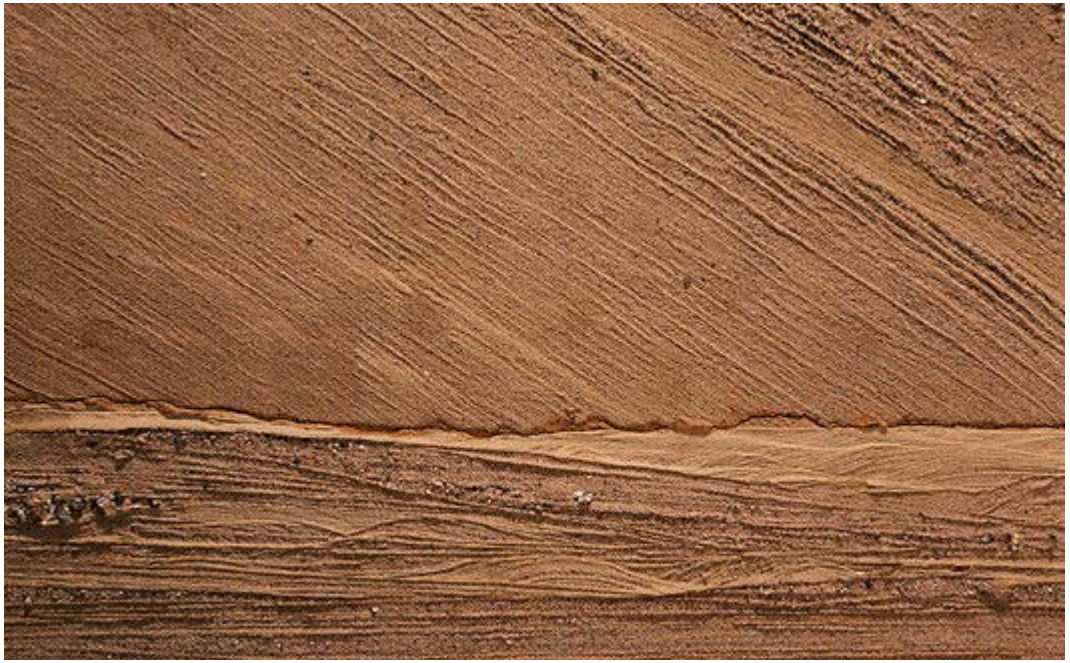


CHALK LIMESTONE

SEDIMENTARY STRUCTURES: BEDDING



CROSS BEDDING



RIPPLE MARKS

MUD CRACKS

MARINE FOSSILS

PLANT FOSSILS

Metamorphic Rocks

- Metamorphic rocks are rocks that have formed by the alteration of pre-existing igneous, sedimentary, or other metamorphic rocks.
- This alteration occurs when the pre-existing rocks are subjected to increased temperature, pressure, or acted upon by chemically active fluids.
- The changes which occur are both textural (changes in grain size and shape) and mineralogical (recrystallization and growth of new minerals).

METAMORPHIC ROCKS

SLATE

SCHIST

METAMORPHIC ROCKS

GNEISS

MARBLE