Earth Formation & Geological Time

The age of the Universe can be constrained from the ages of the oldest stars and by estimating the rate of expansion (Hubble Constant). The Big Bang is currently thought to have occurred at 13.7 Ga (i.e. 13.7 billion years ago).

Formation of the Solar System Material rushing outward from the Big Bang did not form a uniform cloud. Gravitational instabilites in the interstellar cloud collapsed to form *nebulae*. The collapsing cloud span increasingly rapidly because of conservation of angular momentum. The cloud fragmented to form many *galaxies*. Galaxies were initially roughly spherical but flattened into disks as they continued to spin.

Formation of Planets Planet formation began with accretion of cm-sized particles from the cloud forming the galactic disc. Physical collision then produced *planetesimals*. Gravitational accretion became important, forming bodies on scales of 10–100 km. Accretion continued to form *proto-planet* on scales of 100–1000 km.

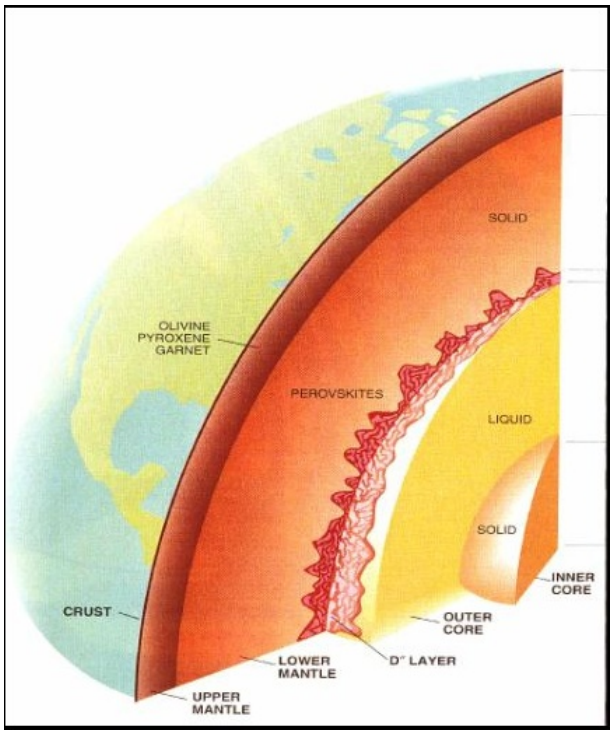
Formation of the Earth The proto-Earth heated up through a combination of meteorite impacts, gravitational contraction and radioactive decay. Eventually, it melted and differentiated to form a Fe-Ni metallic core surrounded by a mantle of Fe-Mg silicates. The new mantle began to expel incompatible gasses. Some of the expelled material was held near Earth's surface to form the oceans and atmosphere. Our knowledge of these stages of planet formation and differentiation comes from the study of *meteorites*.

Measuring geological time Scientists have attempted to measure the age of the Earth and the passage of geological time using many methods. Methods which do not work include *religous theory*, *ocean chemistry* and *planetary cooling* [1]. Absolute age is measured by radiometric dating [2]. Relative age can be deduced by correlating layers of sediment and periods of uplift, erosion and deformation (*stratigraphy*). Evolution of organisms through geological time means that relative age can be deduced from the characteristic fossils contained in many rocks (*biostratigraphy*). High-resolution tuning of the geological timescale is now possible by studying climatic fluctuations induced by changes in Earth's orbit (down to 1000s Myr) [3].

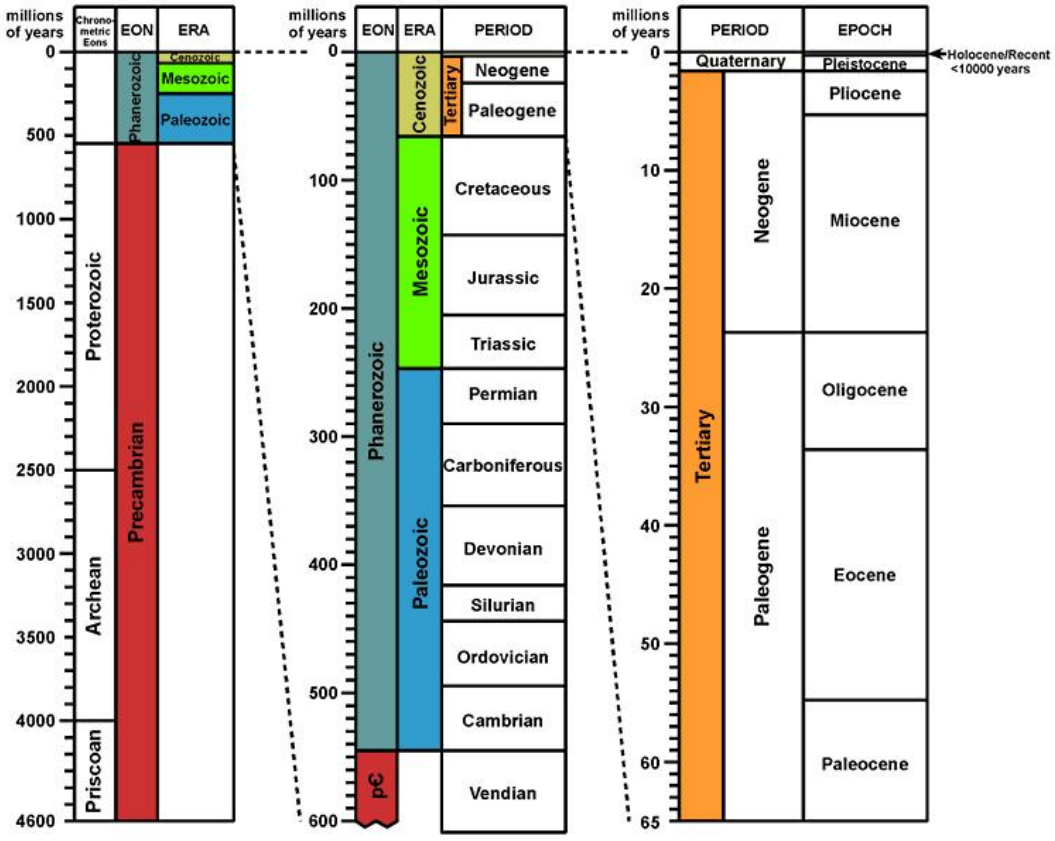
Universe formed	13700 Ma
Earth formed	4540 Ma
Oldest mineral	4400 Ma
Oldest volcanic rocks	4030 Ma
Oldest sedimentary rocks	3800 Ma
Oldest life (algae)	3400 Ma
Oldest land creature	428 Ma
Oldest Hominids	4–5 Ma
Homo sapiens	0.13 Ma

Age of the continents and oceans The mineral *zircon* forms by mantle melting in the presence of water and is a minor constituent of granite. Continents are formed predominantly of rocks of granitic composition. Identification of zircon crystals aged 4404 Ma therefore means that both liquid oceans and continental crust were present very early in Earth's history [4].

[1] See *The Chronologers Quest: The search for the age of the Earth* by Patrick Wyse Jackson of TCD Geology Department (Lecky 551.7 P6)
[2] The Solid Earth §6
[3] See handout on Climate
[4] `www.nature.com/nature/journal/v409/n6817/409175A0.html`



GEOLOGIC TIME SCALE
(Based on data from Gradstein and Ogg, 1996 (Phanerozoic); and Harland et al., 1990)



References:
Harland, W.B. *et al.*, 1990. A Geologic Time Scale, 1989 edition.
Cambridge University Press: Cambridge, 263pp. ISBN 0-521-38765-5
Gradstein, F. and Ogg, J., 1996. A Phanerozoic time scale. Episodes, v.19, no.1&2.