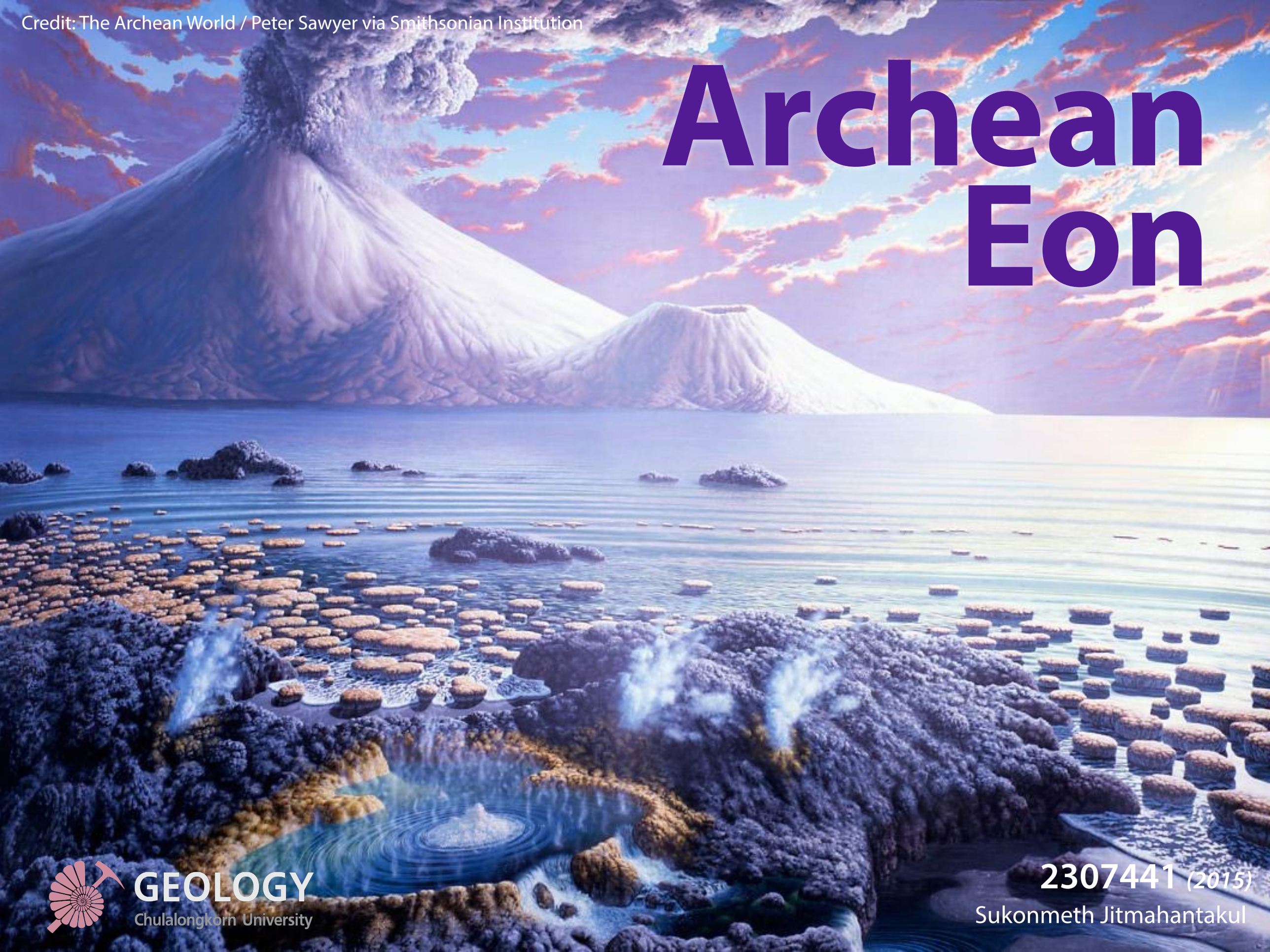


Credit: The Archean World / Peter Sawyer via Smithsonian Institution

Archean Eon

GEOLOGY
Chulalongkorn University

2307441 *(2015)*
Sukonmeth Jitmahantakul

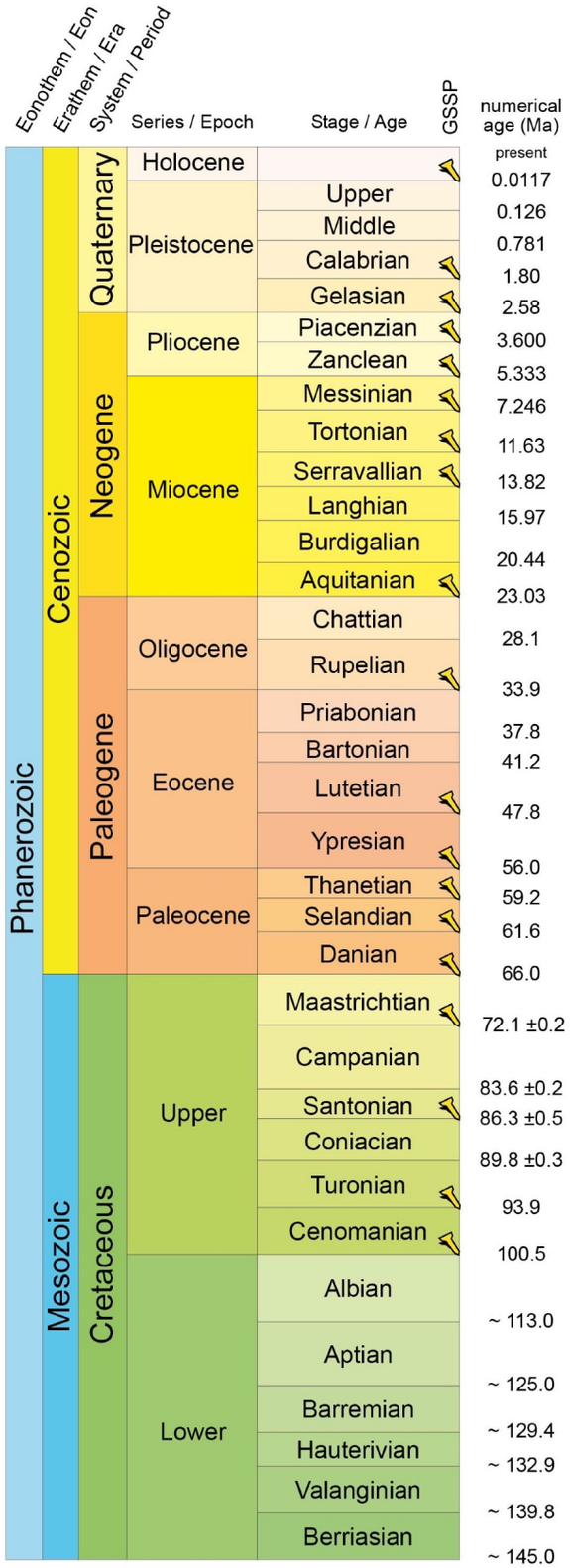
INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

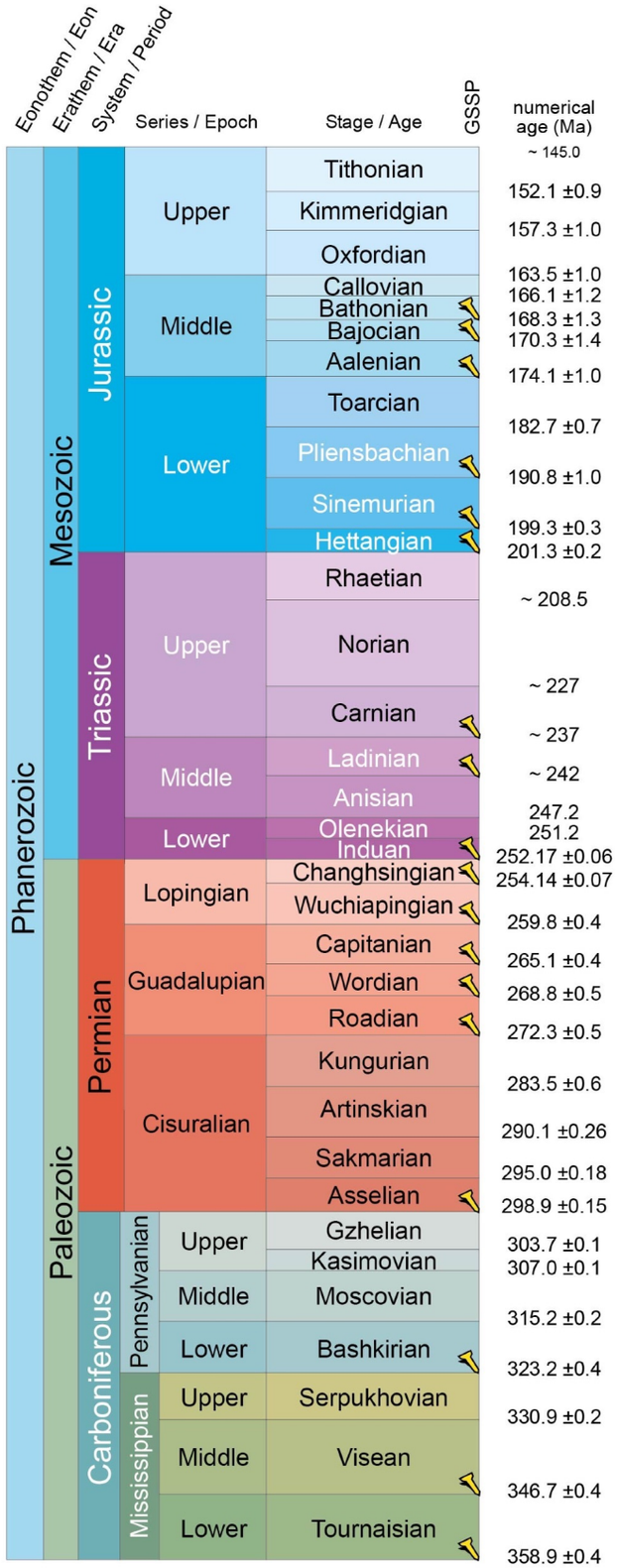
IUGS

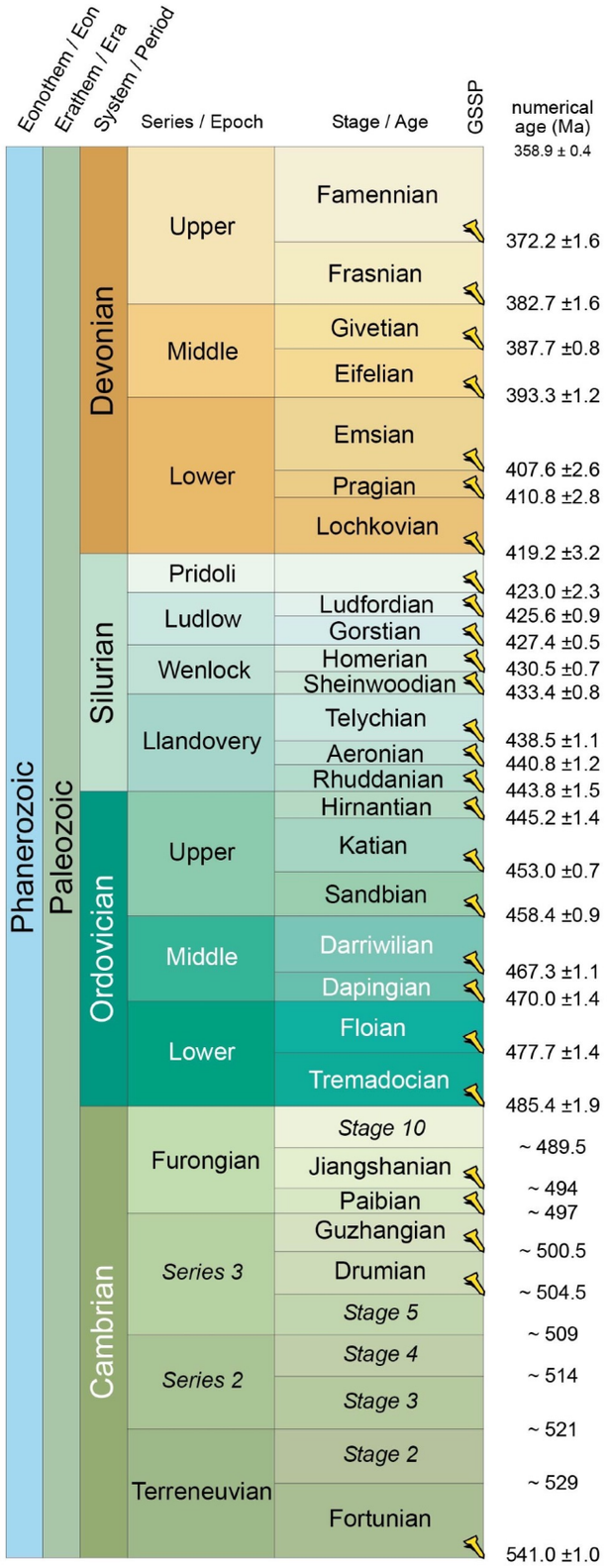
www.stratigraphy.org

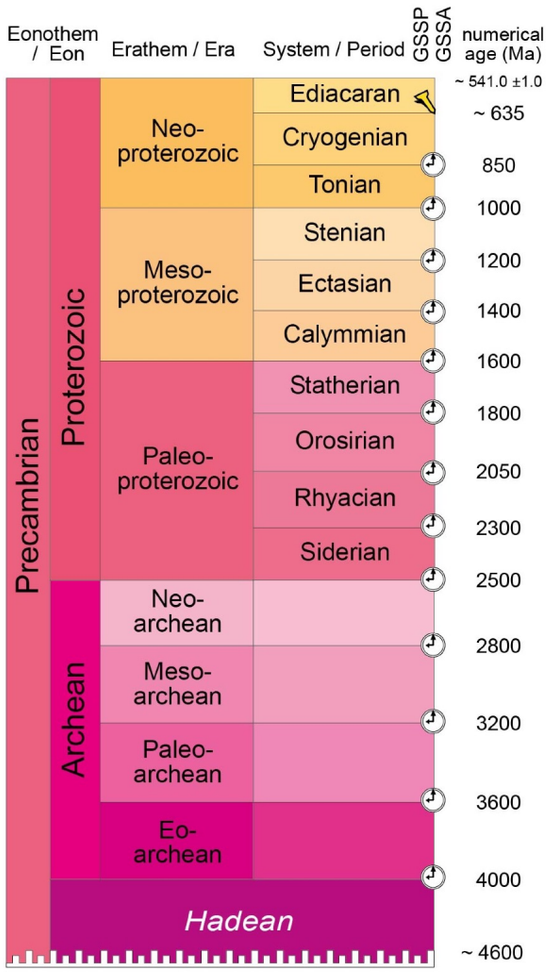
International Commission on Stratigraphy

v 2014/10









Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Numerical ages for all systems except lower Pleistocene, Permian, Triassic, Cretaceous and Precambrian are taken from 'The Geologic Time Scale 2012' by Gradstein et al. (2012); those for the lower Pleistocene, Permian, Triassic and Cretaceous were provided by the relevant ICS subcommissions.

Coloring follows the Commission for the Geological Map of the World (http://www.ccgm.org)

CCGM CGMW

Chart drafted by K.M. Cohen, S.C. Finney, P.L. Gibbard

To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

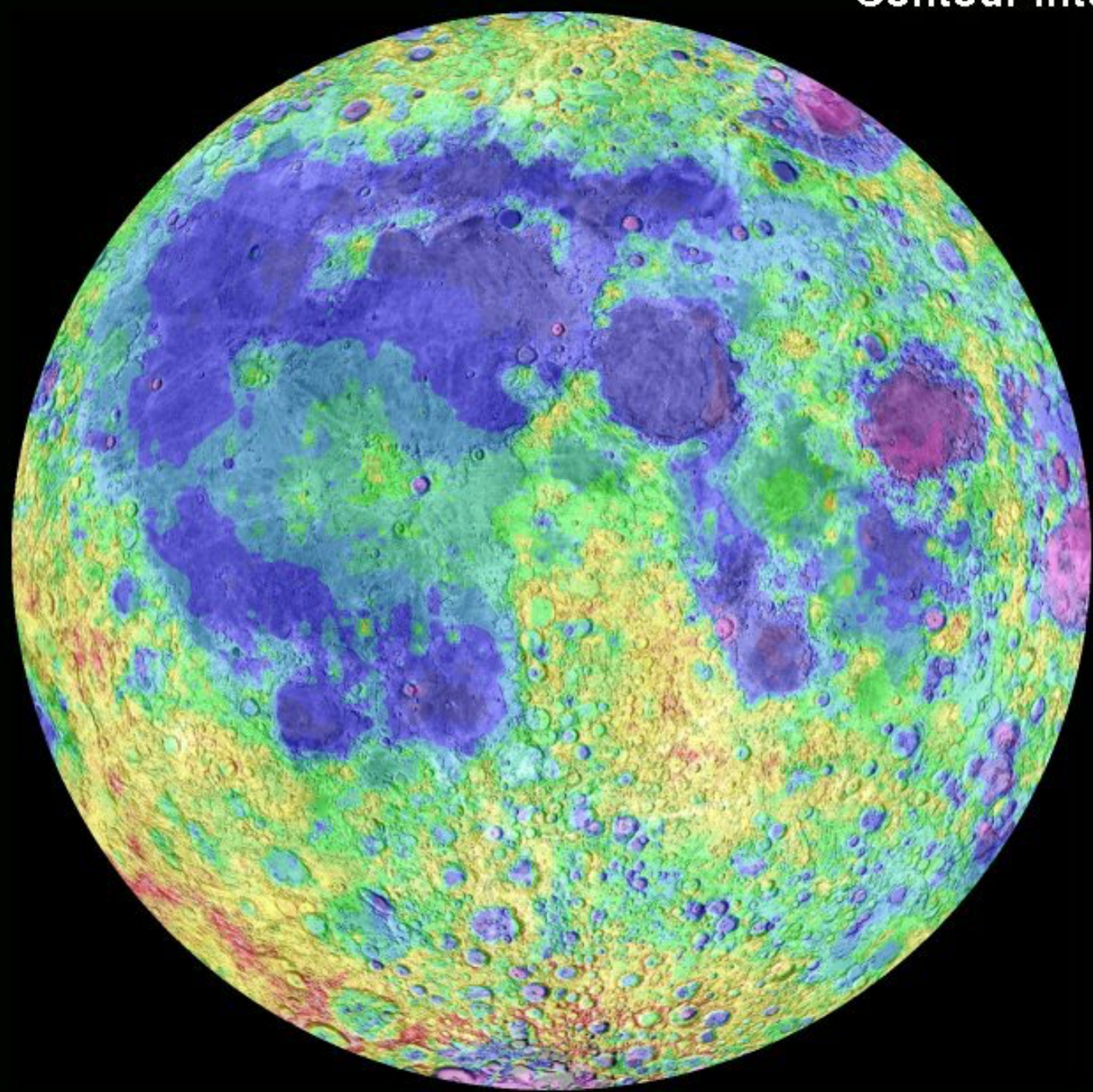
URL: http://www.stratigraphy.org/ICSchart/ChronostratChart2014-10.pdf

Age of the Earth

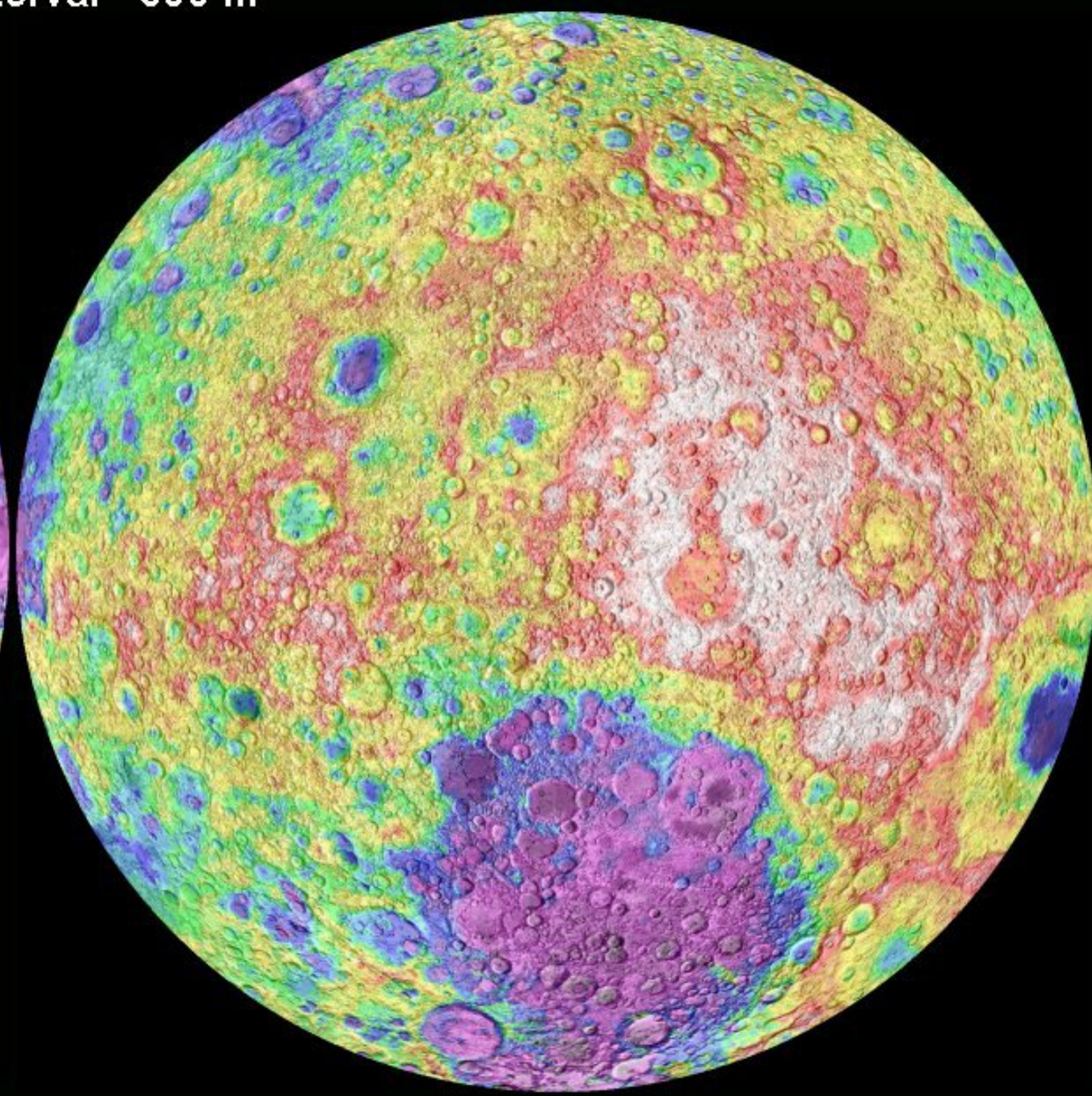
- *[assumption] The Earth and the rest of the solid bodies in the Solar System formed at the same time and are, therefore, of the same age.*
- *The oldest dated **moon rocks** have ages between 4.4 and 4.5 billion years*
- *The **best age** for the Earth (4.55 Ga) is based on old, presumed single-stage leads coupled with the Pb ratios in troilite from **iron meteorites**, specifically the Canyon Diablo meteorite.*
- *Evidence of Earth's oldest crust, which consists of grains of **zircon** in metamorphosed sediments in Western Australia. These zircons are 4.4 billion years old. - **oldest material** on earth - not rock!*

Clementine Topographic Map of the Moon

Contour Interval - 500 m



Near Side



Far Side

Kilometers

Meteor Crater, also known as Barringer Crater *(credit: NASA Earth Observatory)*

Aerial view of Arizona Meteor Crater, September 2010 (*credit: Shane.torgerson*)

Geochimica et Cosmochimica Acta, 1956, Vol. 10, pp. 230 to 237. Pergamon Press Ltd., London

Age of meteorites and the earth

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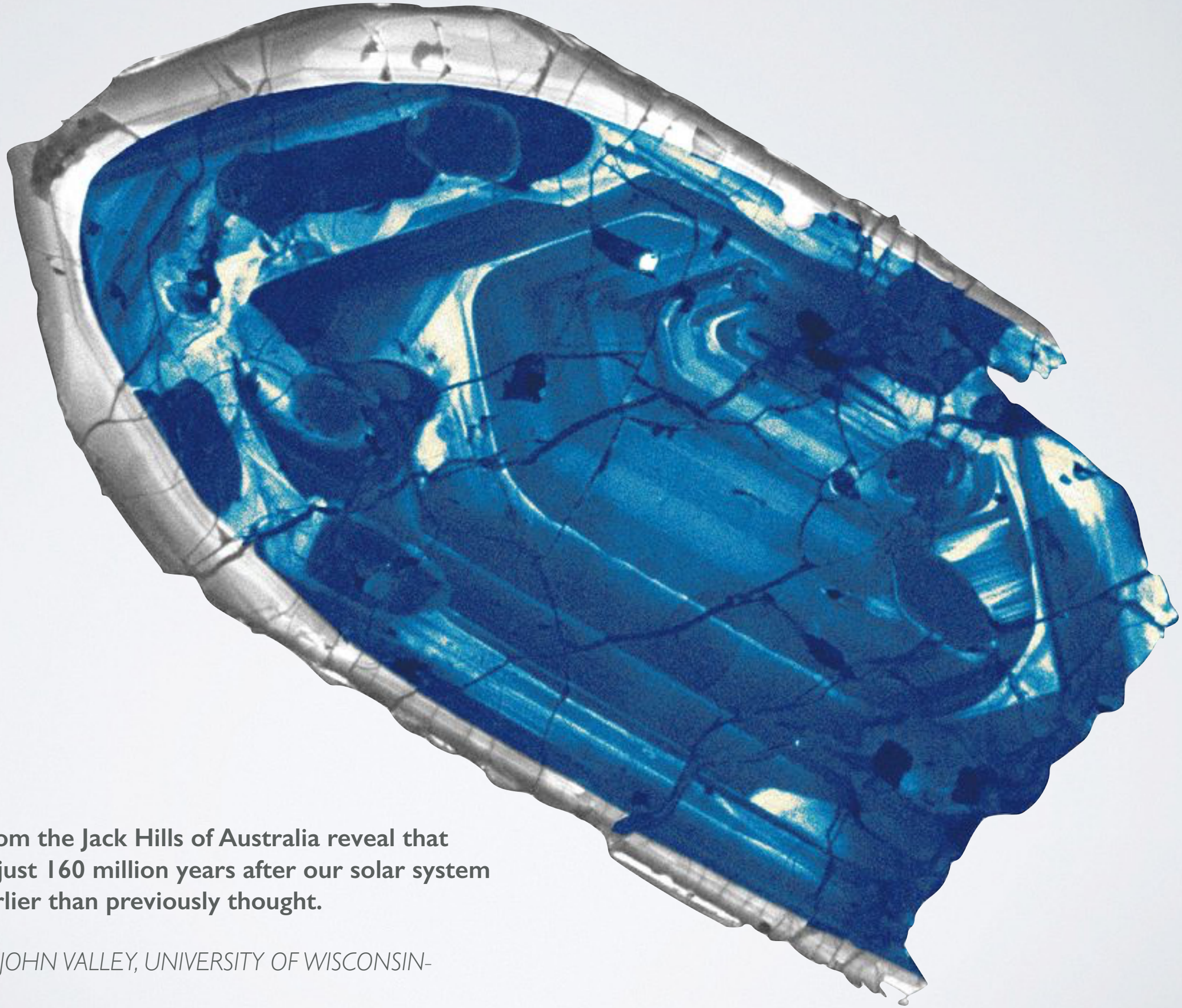
(*Received* 23 *January* 1956)

Abstract—Within experimental error, meteorites have one age as determined by three independent radiometric methods. The most accurate method (Pb^{207}/Pb^{206}) gives an age of $4{\cdot}55 \pm 0{\cdot}07 \times 10^9$ yr. Using certain assumptions which are apparently justified, one can define the isotopic evolution of lead for any meteoritic body. It is found that earth lead meets the requirements of this definition. It is therefore believed that the age for the earth is the same as for meteorites. This is the time since the earth attained its present mass.



Zircon crystals from the Jack Hills of Australia reveal that continents arose just 160 million years after our solar system formed, much earlier than previously thought.

(PHOTOGRAPH BY JOHN VALLEY, UNIVERSITY OF WISCONSIN-MADISON)

nature geoscience

Hadean age for a post-magma-ocean zircon confirmed by atom-probe tomography

John W. Valley, Aaron J. Cavosie, Takayuki Ushikubo, David A. Reinhard, Daniel F. Lawrence, David J. Larson, Peter H. Clifton, Thomas F. Kelly, Simon A. Wilde, Desmond E. Moser & Michael J. Spicuzza

Affiliations | Contributions | Corresponding author

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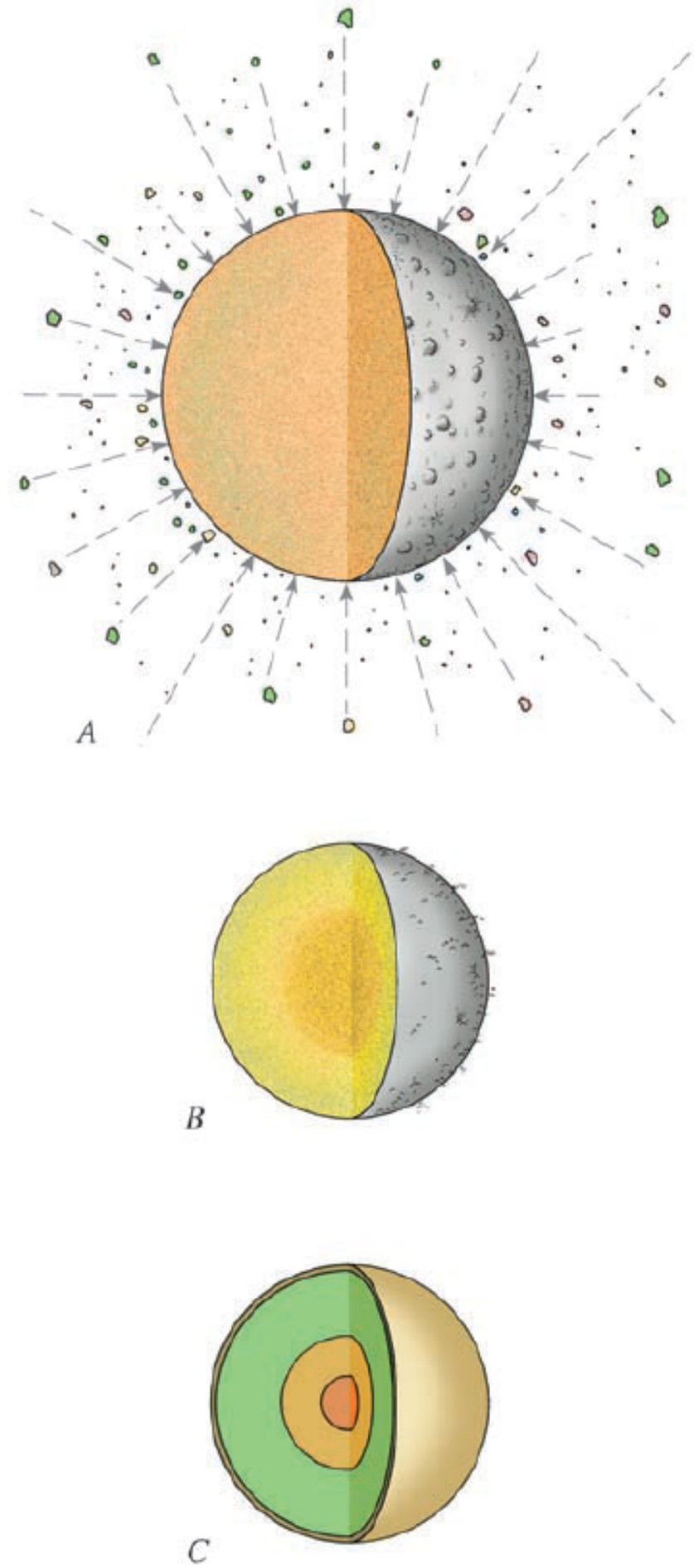
The only physical evidence from the earliest phases of Earth's evolution comes from zircons, ancient mineral grains that can be dated using the U–Th–Pb geochronometer[1]. Oxygen isotope ratios from such zircons have been used to infer when the hydrosphere and conditions habitable to life were established[2, 3]. Chemical homogenization of Earth's crust and the existence of a magma ocean have not been dated directly, but must have occurred earlier[4]. However, the accuracy of the U–Pb zircon ages can plausibly be biased by poorly understood processes of intracrystalline Pb mobility[5, 6, 7]. Here we use atom-probe tomography[8] to identify and map individual atoms in the oldest concordant grain from Earth, a 4.4-Gyr-old Hadean zircon with a high-temperature overgrowth that formed about 1 Gyr after the mineral's core. Isolated nanoclusters, measuring about 10 nm and spaced 10–50 nm apart, are enriched in incompatible elements including radiogenic Pb with unusually high $^{207}Pb/^{206}Pb$ ratios. We demonstrate that the length scales of these clusters make U–Pb age biasing impossible, and that they formed during the later reheating event. Our tomography data thereby confirm that any mixing event of the silicate Earth must have occurred before 4.4 Gyr ago, consistent with magma ocean formation by an early moon-forming impact[4] about 4.5 Gyr ago.

The Archean Crust

- *About 4.55 million years ago, Earth was composed of a random mixture of space debris.*
- *The modern Earth is an internally* ***differentiated*** *planet with three distinct layers. Each layer has a different chemical composition and density.*
- *Once differentiation had occurred, Earth's crust was dominated by iron and magnesium silicates.*
- *As a result of the melting, an extensive magma ocean may have covered Earth's surface.*



Characteristics of Earth's Early Oceanic and Continental Crust

zircon

	Oceanic Crust	Continental Crust
First appearance	About 4.5 billion years ago	About 4.4 billion years ago
Where formed	Oceanic ridges (spreading centers)	Subduction zones
Composition	Komatiite-basalt	Tonalite*-granite
Lateral extent	Widespread	Local
How generated	Partial melting of ultramafic rocks in upper mantle	Partial melting of wet mafic rocks in descending slabs

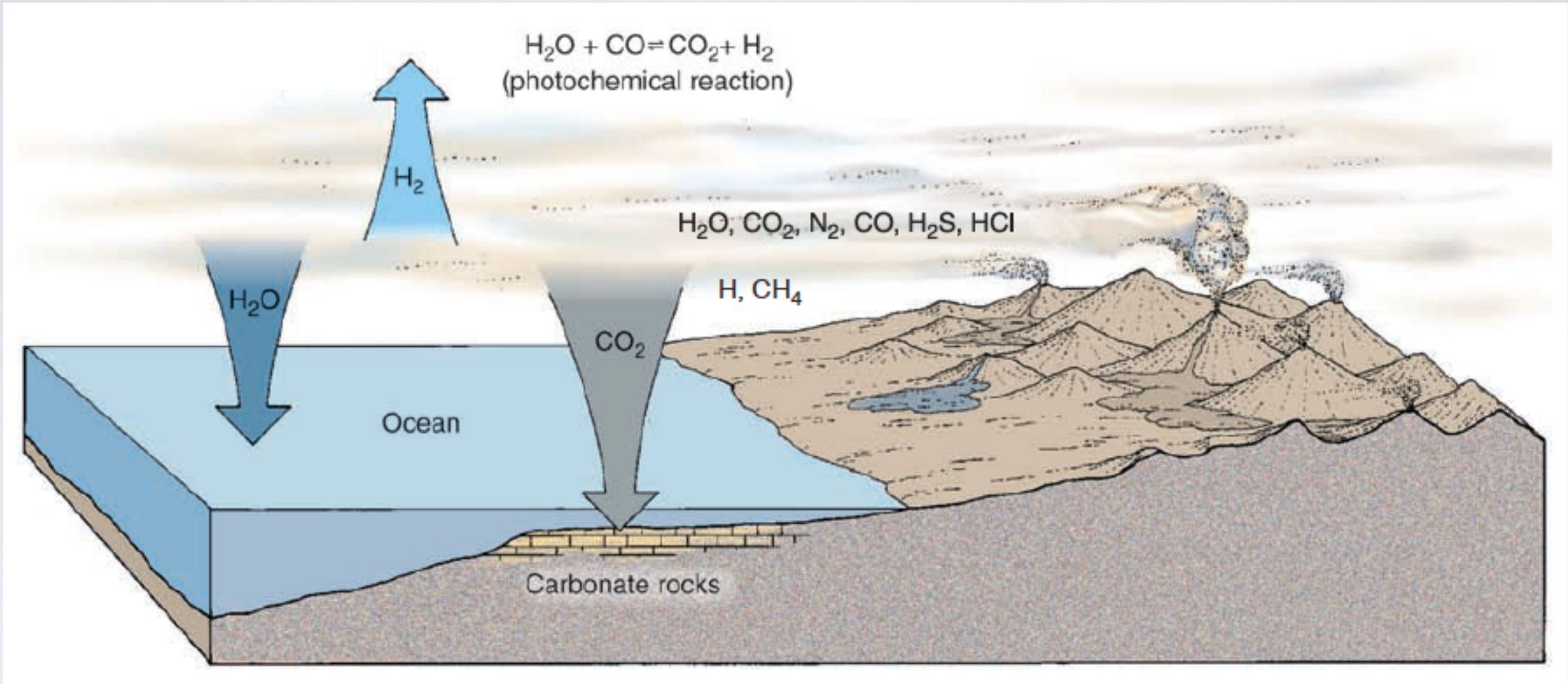
Source: Condie, K. C. 1989. Origin of the Earth's crust. *Paleography, Paleoclimatology, Paleoecology* 75:57–81. Used with permission.

* Tonalite is a variety of diorite containing at least 10% quartz.

- ***Komatiites*** *are ultra-rich in the elements iron and magnesium. They form at temperatures greater than the 1100ºC required to melt basalt.*

The Primitive Atmosphere

- *Before 3.8 billion years ago, Earth's Archean atmosphere had essentially **0% oxygen**, not the 21% we have today.*
- *Archean air consisted mostly of water vapor, carbon dioxide, nitrogen, and lesser amounts of other gases.*
- ***Outgassing** is the process by which water vapor and other gases are released from rocks.*



- *Water vapor condensed and fell as rain, filling low basins to form the **seas**.*
- *Carbon dioxide and other gases that were dissolved in the rain made seawater considerably more **acidic** than today.*
- *This acidity caused rapid **chemical weathering**, which added **calcium**, **magnesium**, and other ions to seawater.*
- *Much later, when the seas became **less acidic** and **oxygen** more prevalent, these ions would join with carbon dioxide to form limestones and the shells of myriad marine organisms.*

Geologic Clues to Early Atmospheres

- *There are **few oxidized iron minerals** from that time. With little oxygen available, iron combined with sulfur to form sulfides like pyrite.*
- *Archean rocks are **often dark** because they contain unoxidized iron (which would have been oxidized to red in an oxygen-rich environment).*
- *The Archean atmosphere was **rich in carbon dioxide**, which combines with water to form **carbonic acid**.*
- *In such an acidic environment, **alkaline rocks** like limestone and dolomite cannot develop. This may account for the absence of carbonate rocks from this early stage of Earth history.*

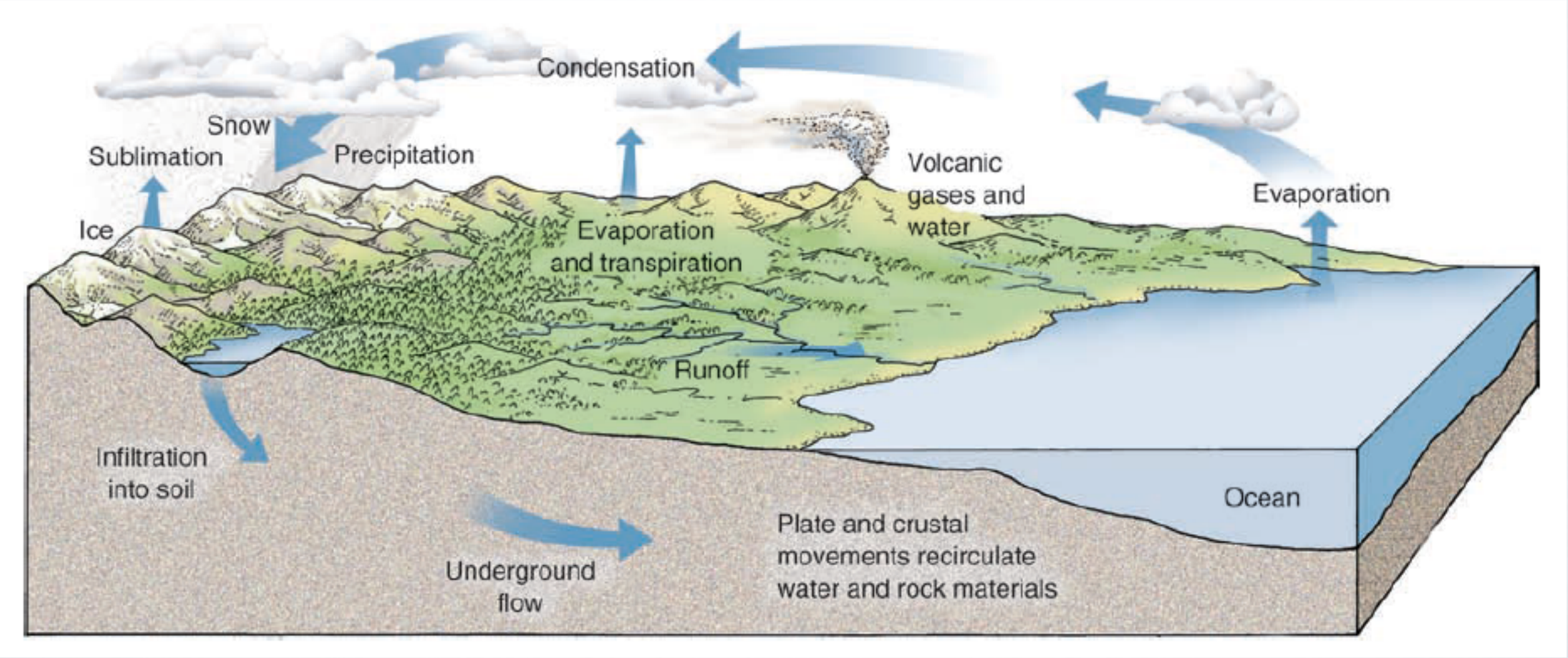
Geologic Clues to Early Atmospheres

- *In rocks younger than 1.8 billion years, evidence of free oxygen in the atmosphere is seen in **Proterozoic red shales, siltstones,** and **sandstones** derived from weathering of older rocks on the continents.*
- *We also find carbonate rocks (dolomites and limestones) of about the same age.*
- *We infer that oxygen gradually began to appear in Earth's early atmosphere from rocks called **banded iron formations (BIFs)***
- *BIFs are **cherts** that exhibit alternating bands of dark rust-red and light gray.*

Banded iron formation, Karijini National Park, Western Australia
(image credit Graeme Churchard)

The Primitive Ocean & the Hydrologic Cycle

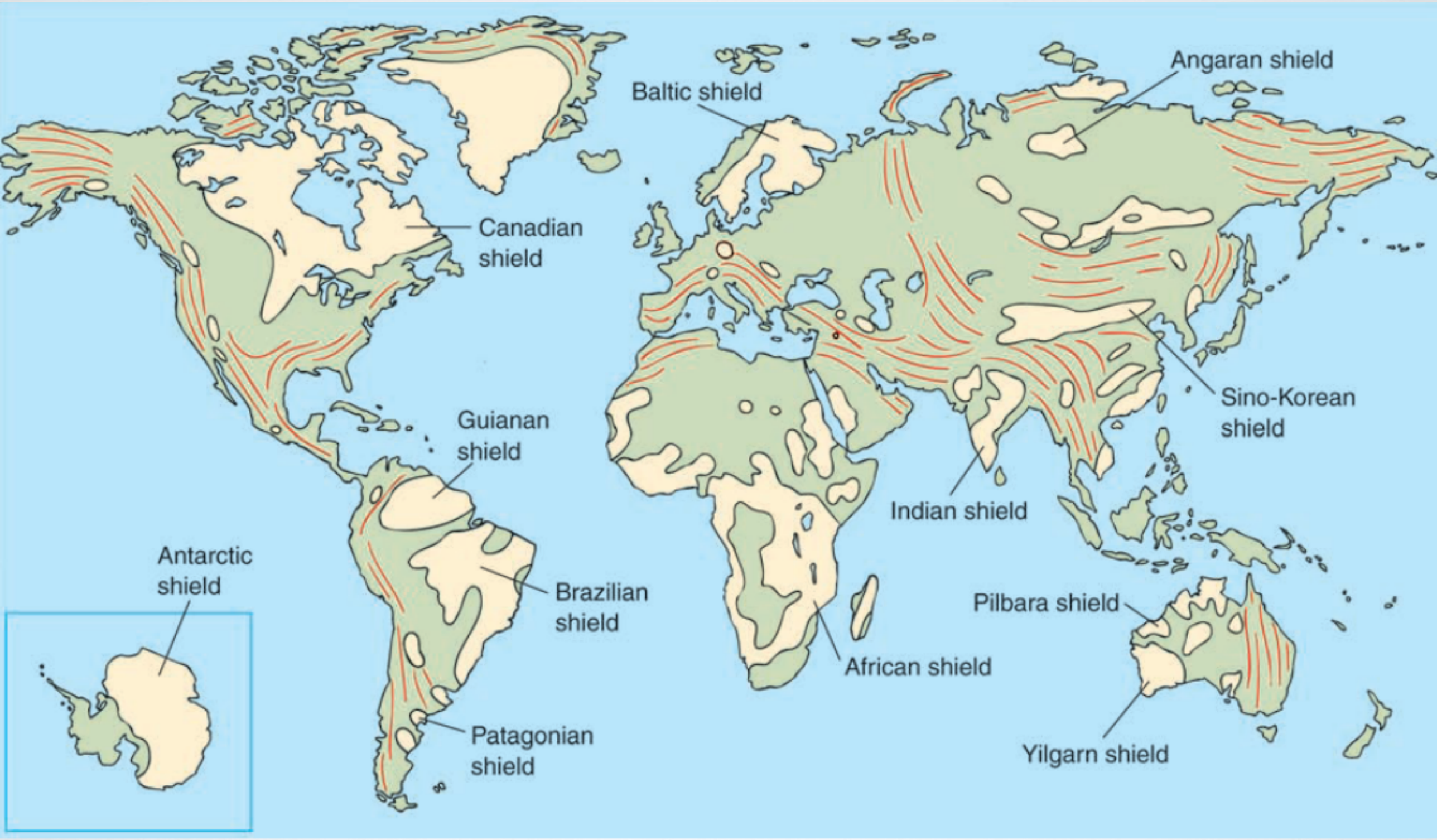
- *Could the enormous volume of ocean water have come from Earth's interior alone?*
- ***Yes.*** *Vast amounts of water were locked within minerals in the accreted Earth.*



Precambrian Basement Rocks

- *Geologists agree that the only reliable way to correlate fossil-less Archean and Proterozoic rocks is through **radiometric dating**.*
- *The most extensive exposures of Precambrian rocks are in geologically stable regions of continents called **shields**.*
- *Such stable regions where basement shields are blanketed by sedimentary strata are called **platforms**.*
- *The platform of a continent, together with its shield, constitutes that continent's **craton**.*

Exposed Precambrian rocks



Origin of Life