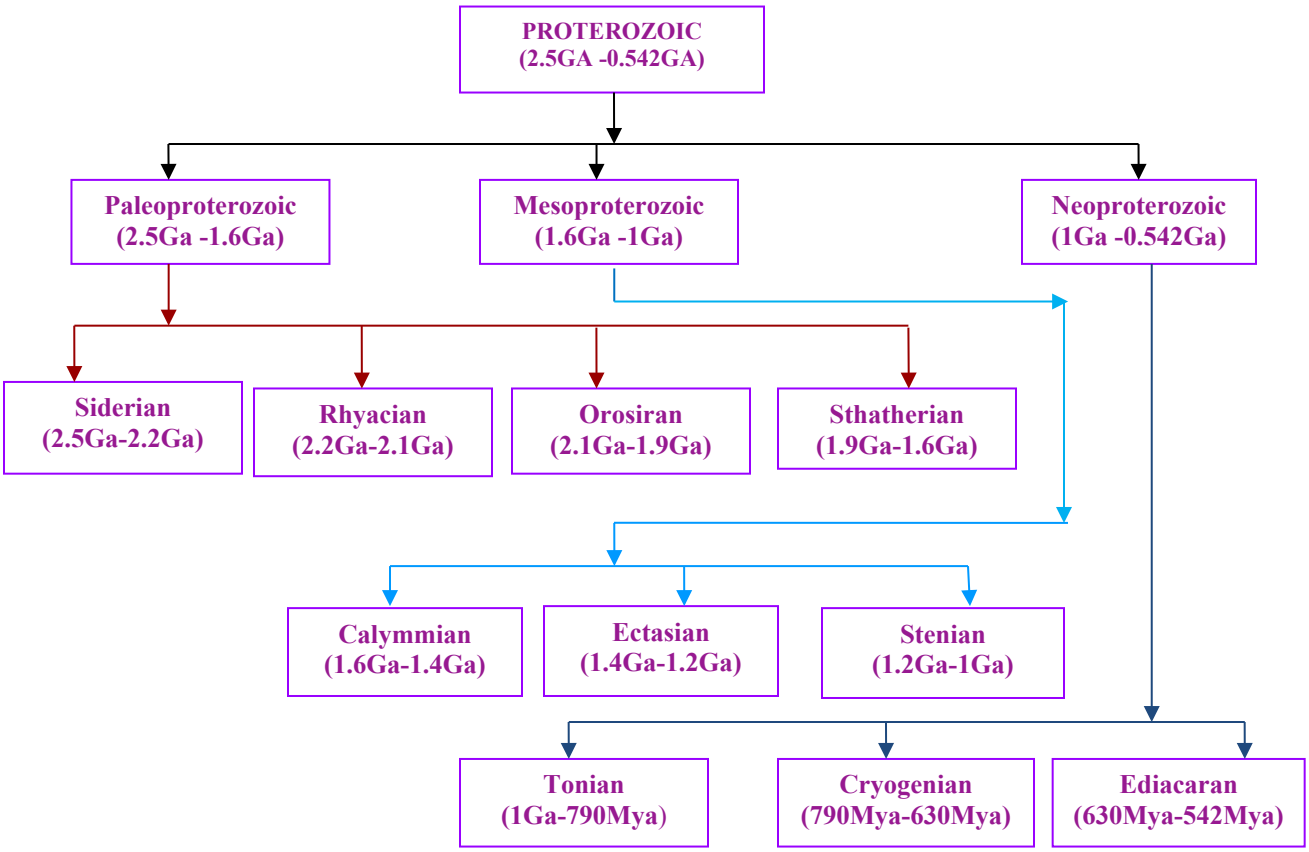
Climate Change, Transformation of Earth and Evolution of Life

Introduction

Nature does not reveal her mysteries once and for all. Knowledge is unfolded through long successive ages. Science of today has revealed to us a Universe so ancient and so vast that human affairs seem to be of little consequences. Many discoveries are reserved for ages to reveal to us so many other things which we do not know now. Today we know from the fossil records about the origin of life. The first living thing was a one-celled organism. Over a long period of time, a molecule, perhaps by accident, arose that could make crude copies of itself, using other molecules as building blocks. The earliest ancestor of deoxyribonucleic acid (DNA), the master molecule of life was thus evolved. Then came the first multicellular organism as a result of joining together a number of one celled organism. After about one billion years, evolution of sexual reproduction took place. With the invention of sex, two organisms could exchange their DNA code, producing new varieties of organisms. All of them did not engage in sex. The ones that found it uninteresting became extinct. Creation is followed by destruction. The transition from hydrogen-rich to an oxidizing atmosphere perished a great many organisms. The monopolizing grip of the algae for a period of about four billion years was then broken by an event called Cambrian explosion after which an enormous proliferation of new life forms emerged. This is what we know as creative destruction. ***This issue of June is devoted*** to the exploration of what happened during a long period of about two billion years from 2.5 Ga[(1)] to 542 Mya[(2)], known as ***PROTEROZOIC Eon***. This Eon is the longest Eon under Precambrian Era. Figure 1 captures its Tree Diagram. It has three main branches and ten sub branches.

[(1)] **Ga** means billion years ago
[(2)] **Mya** means million years ago

Figure 1: Tree Diagram of Proterozoic Eon



During the early period of about 900 million years, the super continents and continents formed during the later part of Archean Eon got stabilized. The main events that occurred during this Eon were: ***Transition from non-oxygenated to an oxygenated atmosphere and extensive formation of Banded Iron Formations (2.5 Ga to 1.6 Ga); severe glaciations forming Snowball Earth – first during 2.5 Ga to 2.1 Ga and second, during Crygenian period (750 Mya to 630 Mya); Sudden eruption of volcanoes (2 Ga); collision of large asteroid with the Earth on two occasions (2 Ga to 1.8 Ga); Evolutions of Eukaryotes (1.5 Ga), a two celled bacteria; beginning of formation of mountains; Formation of a new supercontinent, called Columbia (1.8 Ga) as a result of joining together of three continents (Ur, Atlantica and Nena) formed earlier; Break-up of Columbia (1.5 Ga); Accumulation of a distinct group of sedimentary Rocks (1.4 Ga); Evolution of sexual reproduction (1.2 Ga); Formation of supercontinent, called Rodinia (1.2 Ga); Break-up of Rodinia (750 Mya); Formation of second Snowball Earth (750 – 630 Mya); Formation of second supercontinent, called Pannotia (600 Mya) and evolution of soft-bodied multicellular organisms (630 Mya to 542 Mya) which provided the scientist with the first fossil evidence of life on Earth.***

The Great Oxygenation and Mass Extinction of Bacteria

With vigorous growth of Cyanobacteria, oxygen sinks became saturated and oxygen produced by them started escaping into the atmosphere. The surplus oxygen caused build up of oxygen about twenty times, which changed the composition of ocean water and atmosphere. This event is known as the Great Oxygenation event or Oxygen catastrophe. This oxygen being toxic caused mass extinction of countless species of bacteria excepting a few primitive forms, such as ***botulism and tetanus bacilli***.

Banded Iron Formations (2.5 Ga to 1.6 Ga) [(3)]

Banded Iron Formations (BIFs) which started appearing in the Archean Eon (4 Ga to 2.5 Ga) became widespread in the Paleoproterozoic Eon (2.5 Ga to 1.6 Ga). Irons derived from the weathering of iron-rich rocks got mixed up with ocean water as soluble-Fe^{2+} and increased its iron content. These irons reacted with excess oxygen and formed magnetite (Fe_3O_4) which changed the colour of ocean water from green to clear. Colour of banded iron corresponded to the concentrations of oxygen levels. With high oxygen level, colour was rust-red and with low oxygen level, colour was gray. A banded iron sequence now found in Lake Superior (North America) is known as Gunflint Chert which even today contains well preserved prokaryotic organisms.

Glaciations and Snowball Earth (2.5 Ga to 2.1 Ga)

A portion of excess oxygen reacted with methane producing carbon dioxide and water. Level of methane which kept the planet warm started declining. Earth began to lose heat and ultimately, it cooled. As a result, ocean water were frozen creating massive glaciations. When the entire planet got frozen, it looked like a 'Snowball'. This event, known as ***Huronian glaciations,*** is the oldest and longest ice age covering a period of about 400 million years during the Siderian and Rhyacian periods (2.5 Ga to 2.1 Ga). With temperature of Earth cooling down, movements of the primitive plates and rocks inside the Earth caused a gap. This helped create convection whereby there was high volcanism and flow of lava on the Earth's surface from inside. This caused rich deposition of igneous rocks rich in heavy minerals. This intense volcanism produced greenhouse

[(3)] Banded Iron formations are fine-grained sedimentary rocks that show alternating bands of dark red and light gray colour. The dark red bands are made up of hematite and magnetite. The light gray bands are chemically precipitated quartz.

gases mainly comprising of carbon dioxide and monoxide which increased the temperature of the Earth's surface and atmosphere. With increase of temperature, glaciations ended gradually around 2.1 Ga.

Evolution of Eukaryotes (around 1.5Ga)

Oxygen generating green algae and prokaryotes which existed from the early period increased oxygen content in the atmosphere. This allowed formation of ozone layer and in turn, created a proper environment for the evolution of new types of bacteria. Evolution of Eukaryotes was the result of this change. They first evolved about 2 billion years ago in the form of one small and one large independent bacterial cells. The large cell engulfed small cell. The small cells were not digested by large cells. Instead, they lived within large cells in a **symbiotic relationship** in which both cells benefited. In the process, they evolved organelles comprising of mitochondria and chloroplasts of eukaryotic cells.

Collision of Asteriods (2.1 Ga to 1.9 Ga)

During the Orosirian period, a large asteroid collided with the Earth creating the largest impact crater, now known as '***Vredefort***' crater found in South Africa. The second largest collision occurred 1.8 Ga creating the crater now known as '***Sudbury Basin'*** found in Canada which provides large scale mining operations for nickel and copper.

Formation of Supercontinent Columbia (around 1.8Ga) and its breakup (1.5 Ga)

Tectonic plate movements caused the three continents, namely, Ur, Atlantica and Nena formed during Mesoarchean and Neoarchean Eras, to drift together and they expanded through accretion. This gave rise to the first supercontinent Columbia during the end of the Orosiran period. Columbia, however, suffered a major break up during the Calymmian period (1.5 Ga). During this period, a distinctive group of very ancient multicoloured sedimentary rocks now known as ***Belt Supergroup*** and ***Green Ville Orogeny***, now found in North America and Western Europe were also formed.

Evolution of Sexual Reproduction (around 1.2Ga)

Invention of sex might have been made with evolution of Eukaryotes. Perhaps, it was necessitated as evolution of life was very slow. Even then, it took about 300 million years to experience sexual reproduction system in the evolution process of life. Records of Eukaryotic

fossil show that ***Bangiomorpha pubescens***, a red algae, was the first organism to carry out sexual reproduction. Sexual reproduction occurred when two morphologically distinct types of specialized reproductive cells, called gametes, fused together. Each gamete contains half the number of chromosomes of normal cells. Division of Eukaryotic cell occurred by a process known as ***meiosis*** by which two gametes used to be fused during fertilization producing a single celled ***zygote***. This eukaryotic zygote contains the genetic material (DNA) from both the gametes. The cell has two set of chromosomes – one derived from the mother and the other derived from the father commonly known as homologous chromosomes. A process known as genetic recombination then occurred in which the homologous chromosomes got paired up followed by the exchange of genetic information. With invention of sex, two organisms thus exchanged their DNA code, producing new varieties ready for the next selection. Those that found sex uninteresting became extinct.

Formation of Supercontinent Rodinia (about 1.2Ga)

Rodinia was formed by the accretion and collision of fragments produced by breakup of the older supercontinent, ***Columbia***. Earlier Rodinia was completely a barren land with less traces of life, the centre of which was a vast floodplain containing old deposits of sediments and silts. Massive floods were common on the continent. It was surrounded by a single large ocean, known as ***Mirovia***. This supercontinent changed the ocean currents that had led to the snowball Earth later in the Cryogenian period (790 to 630 Mya).

Break up of Rodinia and Sturtian and Marinoan Glaciations (790 – 630 Mya)

Rodinia was subjected to the Earth's internal heat. A slow buildup of heat beneath Rodinia caused the continent's crust to dome, stretch and weaken. Eventually, the entire continent ruptured and had split into two parts – Gondwana and Laurasia. With the ongoing break-up of the Rodinia, two major types of glaciations was formed by volcanic activity associated with such break-up. The entire planet became a Snowball for the second time during Proterozoic Eon and it remained for about 100 million years. Since Rodinia was centered on the equator, rates of chemical weathering increased and carbon dioxide was taken from the atmosphere. Thus the climates cooled. Rodinia also prevented the proper flow of ocean currents required for transferring heat between the equator and the poles. The increased humidity and silicate weathering drastically reduced the amount of greenhouse gasses and carbon dioxide in the

atmosphere. Without greenhouse gasses, heat from the sun quickly escaped the atmosphere, lowering earth's temperature. The ice-covered earth reflected sunlight back into space, reducing global temperatures further. Most of the microorganisms that survived got eliminated due to this freezing climate. However, some life continued to persist in the extreme environment caused by the global ice age. Microorganisms, called ***extremophiles***, were able to adapt to the conditions caused by Snowball Earth. Without these survivors, all life on Earth might have come to an end.

End of Snowball Earth

Meanwhile Earth experienced massive volcanic activities underneath the oceans. Magma coming out from volcanoes released carbon dioxide and methane gas in the atmosphere. They produced a greenhouse effect which warmed the planet. Glaciers started melting and finally ended.

Formation of Pannotia (around 600 Mya)

About 600 Mya the cratons of Gondwana and Laurasia combined together to form a supercontinent known as Pannotia which was short lived.

Evolution of Soft-bodied Multicellular Organisms (630 – 542 Mya)

The Ediacaran period represents a turning point in the history of life with the development of multi-cellular life forms. These were ***soft-bodied creatures*** and considered as the ***cnidarians grades***. Their shapes were like a simpler disk. S***ea anemones, hydra, jellyfish, corals*** were among them. They did not have any body parts or organs except for a stomach cavity and a mouth covered with tentacles. Ending the Ediacaran period was the ***Cambrian explosion*** after which an enormous proliferation of new life forms emerged.

Conclusion

If we understand the evolution of life in right perspective, we would realize that our ancestor is same. We are member of a larger group. Our consciousness arose from one-celled organism which evolved about 4 billion years ago. If we look at and try to connect with the nature intensely, we would observe what a marvelous cooperative arrangement all living beings have made amongst themselves for survival. We inhale what plants exhale. The life cycle powered by the nature continues. So, let us survive on a sustained basis for a further period of billions of years by showing respect to the nature.

