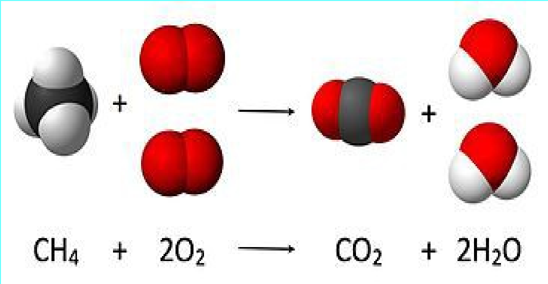
The Triumph of Evolution

Humans

Fire



and the Carbon Cycle

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A Personal Journey with Mankind

I have over the last 5 years made a personal journey, and in this book I hope to convey how I reached my conclusions.

I started out with the knowledge that in the 80's when I studied science at the OU climate was driven by physics and geology, and a vague disquiet that anthropogenic climate change was hysteria. My re-evaluation of the science led me to a belief that humanity and climate were inextricably linked.

The 2 million year plus history of the evolution of humanity has occurred against a backdrop of massive (by Holocene standards) climate change. Population swings have been driven by changing climate. Generally speaking cold periods have driven the population lower and warm periods have led to increasing population such that coincident with the last glacial termination mankind embarked on its greatest adventure.

Is this coincidence or serendipity, the conclusion that I have voiced in other pieces is that human population growth both numerically and geographically has been intimately involved in climate change for the benefit of the current generation. I believe that we accidentally contributed to creation of the Holocene warmth, selfishly and without design.

Nonetheless evolution made us fit to grasp this opportunity, as we have been evolving with and fighting the vagaries of climate for hundreds of thousands of years. We are a tropic evolved species which has adapted too and overcome the ice ages and claimed our place on the earth when the glaciers retreated or were driven back.

The final irony is that the current anthropogenic climate forcing is a direct response to an incipient ice age which would be occurring at the lowest point of the solar cycle i.e. climate forcing of -1.5/2 C since the preceding maximum, with a balancing forcing of + 0.5 C which is just enough to stop us crossing the ice threshold and disappearing under kilometres of cold hard death.

Mike Davies 2010-2015
Junceira

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1. Ten Billion Years of Evolution
From the Big Bang to the Late Heavy Bombardment

The Universe has been evolving for approximately 13.8 billion years, during this time, it has changed from the original hot dense state, to one which is both amicable to and observable by carbon lifeforms.

This has led to much debate on fine tuning and the anthropic principle, and whether there are more than one Universe. For the purpose of his work, I will keep my explanations to the observable universe, which obeys the physical laws with which we are all familiar.

1.1 Baryogenesis and nucleosynthesis

At some finite time interval after the Big Bang the hot energy expanded and cooled sufficiently for matter to coalesce from the primordial state. This process named baryogenesis by physicists, led to the current mix of subatomic particles, protons and neutrons, and after a further short interval, the electron, after the process stopped we were left with the current ratio of 1 neutron to 7 protons.

All of these processes occur in the first few seconds of the Universe and are followed by a period when nuclear fusion takes place, the free neutrons available combine with protons to form deuterium, and finally helium, deuterium is highly unstable, but helium 4 has a high nuclear binding energy, and is extremely stable. The universe does not remain hot for as long as it takes, for Carbon to be synthesised, so the early matter consists of a plasma of hydrogen and helium ions with traces of deuterium tritium and beryllium. After between 3 and 20 minutes the process stops because the temperature and pressure fall. At this point the theory predicts that the matter in the universe is composed of 92 % hydrogen and 8 % helium nuclei by volume with traces of Li and Be.

It is usual to quote this elemental abundance by mass i.e 75 % hydrogen, 25 % helium, this follows from the neutron proton ratio above. 2 neutron + 14 protons . 1 $He4^{++}$ + $12H^{+}$ These abundances equate well with observational data. Further nucleosynthesis stops until after the first stars form, but the universe continues to expand and evolve. The universe remains in this highly ionised state for approximately 400 thousand years until the pressure and temperature drop sufficiently for electrons and nuclei to combine into atoms. This point is marked by the radiation decoupling from matter, and the relic of this event can be observed as cosmic microwave background radiation.

1.2 The first stars

The next 150-800 million years is known as the dark ages, and the history of the Universe is dominated by gravity, and the development of structure, this is not well understood, and the processes are currently the subject of much debate. It is thought that large molecular clouds formed, and that gravitational perturbations led to the birth of massive population III stars with high luminosity and short lifetimes. These low metallicity stars, in stellar evolution low metallicity means that no elements more massive than helium are part of the initial mix, were needed to seed the cosmos with heavy elements.

1.3 Stellar evolution

While the structure of the early Universe is the subject of much debate, stellar evolution is much better understood, It was proposed in 1944 that the galaxy contained 2 populations of stars based on their spectral characteristics, a term now known as metallicity. The younger population I stars like the sun have many more emission lines for heavy elements in their spectra

Population III stars are now proposed in some cosmological theories to have seeded the early interstellar medium with the first heavy elements through a process called pair-instability supernova., associated with the evolution of very low metallicity massive stars. The collapse of these massive stars (up to 250 solar mass) due to gamma rays producing electron positron pairs and reducing radiation pressure in the stars core and a partial collapse. This compressed the core sufficiently that a runaway nuclear reaction caused the core to synthesise heavy elements thought to be mainly Nickel 56. The resulting thermonuclear explosion completely destroys the star and blasts its component materials into the surrounding ISM. The Ni56 eventually decays to Fe56 which is stable

1.4 Stellar Nucleosynthesis

Stellar nucleosynthesis occurs in all stars which are massive enough for hydrogen fusion to occur after the protostars core reaches 10 million degrees K under gravitational pressure. For stars of .5 solar mass or less, stellar evolution is thought to take 100's of billions of years so non have evolved sufficiently for significant nucleosynthesis to have occurred.

For yellow dwarf stars like the sun hydrogen fusion continues for billions of years but eventually they will leave the main sequence and evolve into red giants, during the remainder of its life it will eventually fuse helium into carbon via the triple alpha process He + He --> Be + He --> C , this process is highly temperature dependant as Be is unstable. The process continues with the fusion of Carbon into Oxygen C + He-->O, and possibly Nitrogen

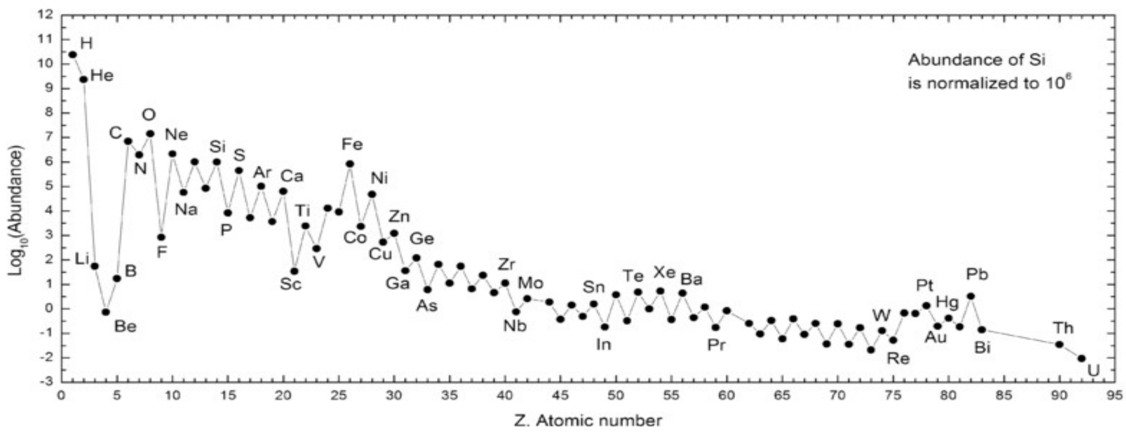
The red giant outer envelope is convective so the products of these reactions become highly mixed and when nuclear fusion stops and the core collapses to eventually become a white dwarf, the hot white star blows off the stellar envelope and the subsequent planetary nebula is enriched in C, O, and N

Slightly more massive stars also synthesise heavier elements up to iron in their cores by alpha process, due to gravitational heating, and also in their envelope by slow neutron capture. These elements may be added to the ISM via supernova, nova or planetary nebula, the exact mechanisms vary with type and size

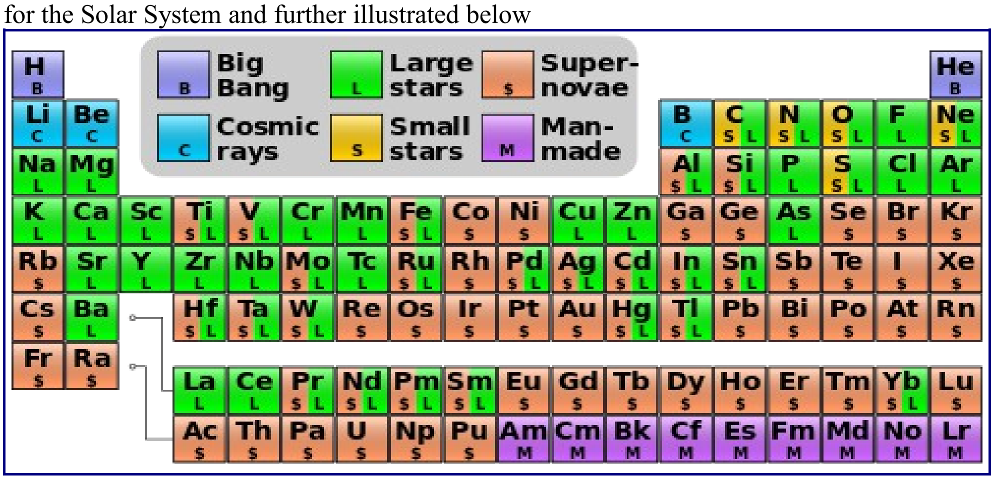
1.5 Massive stars and supernova nucleosynthesis

Several related processes are thought to occur in massive stars but the resulting evolution is dependant on several variables like size and metallicity. Nucleosynthesis and subsequent admixture into the ISM has theoretically occurred since the first massive stars were formed by various explosive stellar phenomena these include nova, supernova and supernova imposters. The synthesis of heavy elements is normally associated with rapid neutron capture when the shockwave associated with the collapse of the stars outer layers causes rapid fusion in the outer shell of the core and the energy released blasts the material into space. A similar process occurs in binary systems when stellar material from a red giant falls onto the surface of its white dwarf companion.

1.6 Elemental Abundance



These and other processes have produced an elemental abundance in the Universe similar to that shown above for the Solar System and further illustrated below



Periodic table showing the cosmogenic origin of each element

So far we have looked at the origins of the elements, and the evolution of these under physical processes, that were the steps necessary for the creation of the basic building blocks of life

1.7 Astrochemistry and Molecular clouds

Many complex molecules have been detected in molecular clouds, most of these molecules are organic, and include polycyclic aromatic hydrocarbons, the most numerous class of carbon compounds in the ISM and meteorites. These compounds are thought to have formed in the earliest molecular clouds and are associated with the formation of the earliest stars.

As these are now thought to be abundant in all molecular clouds they may play a part in the origin of life when planetary systems are formed around new stars.

1.8 Formation of the Solar system

The Solar system coalesced from a seeded molecular cloud approx 5 billion years ago in the Orion Arm of the Galaxy. It s thought that a supernova shock wave caused perturbations in the cloud. A gravitationally bound fragment then coalesces into a solar nebula, the conservation of angular momentum causes the nebula to spin and form a protoplanetary disc, around a protostar. For the sun this process is thought to have taken 100,000 years. The disc flattens out and increases in diameter, and at the same time most of the materials in the nebula are gravitationally attracted to the central protostar and the protostar grows.

1.9 T Tauri phase

This stage in the evolution of the Solar System is known as the T Tauri phase (named after the first such star observed), the conversion of gravitational energy from the accreted matter to kinetic energy causes the central protostar to heat up. These highly variable stars have not yet begun nuclear fusion and are powered by gravitational energy. As they continue to contract they become hotter and denser and eventually hydrogen fusion occurs in the core and the sun became a main sequence star spectral class G2 yellow dwarf This stage lasts for about 50 million years.

1.10 Evolution of the disc

There are competing models for the formations of the planets and their orbits, it is now thought that the terrestrial planets migrated inwards, and that Neptune formed closer to the Sun and was disturbed by gravitational interactions with Jupiter and Saturn.

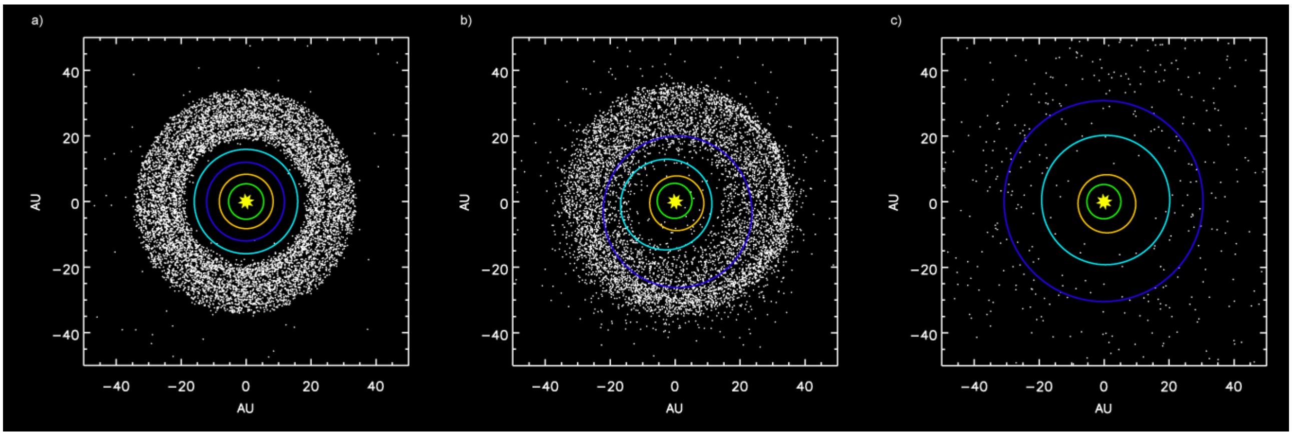
The generally accepted process is called accretion. The early phase was the accretion of rocky planetisimals by gravitational attraction and collision inside the frost line for terrestrial planets, and both rocky and icy planetisimals beyond the frost line for gas and ice giant planets. The frost line for the Solar system is theorised to be 5 AU (Astronomical unit, 1 AU = earth orbital radius). The gas giants had more volatile components available grew faster and have a composition that is mainly Hydrogen and Helium, the terrestrial planets formed in a warmer regio and are composed mainly of heavy elements and are therefore much smaller, as these elements comprised less than 0.06% of the mass of the nebula. Continuing accretion of larger and larger planetisimals over the next 50-100 million years caused the formation of the protoplanetary terrestrial bodies and eventually the 4 planets and the Moon, The gas giant planets Jupiter and Saturn accreted large amounts of Hydrogen and Helium, but the ice giants Neptune and Uranus evolved more slowly, and consequently, are mainly carbon, nitrogen and water ices and only about 20% Hydrogen in their atmospheres

1.11 Planetary differentiation and giant impact hypothesis

During the accretion phase heating of the planetary and protoplanetary bodies by gravity, collisions and radioactive decay led to differentiation of the materials in the bodies, such that heavier atoms like Iron and nickel migrated to the core and lighter materials to the crust. Most Solar System bodies show this differentiation and shell structure. This was also the time when impacts and protoplanetary fusions were still occurring.

While the moon shows some differentiation it is less dense than the earth, and lacks a large iron core. It is hypothesised that the moon may be composed of crustal rocks from the earth, which are the left over debris of a massive impact during the late accretion phase. The evidence for this include density, isotopic signatures and elemental abundance. It is thought that the crust of the moon had been formed by 4.2 billion years ago, as there is evidence for impact and volcanic events after this period. As the moons surface is not subject to weathering later events are superimposed on each other, and the moons surface retains a record of subsequent evolution of the Solar system.

1.12 Planetary migration and the LHB



"Lhborbits" by en:User:AstroMark - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons"

Evidence for the late heavy bombardment can be seen in impact events recorded on the surface of the moon, impact melt rocks brought back from the lunar expeditions show ages clustering between 4.1 and 3.8 billion years ago.The cause of this Late Heavy Bombardment, is thought to be planetary migration and the currently accepted theory is called the Nice model developed there and published in 2005. *Refer to figure above.*

1. The ice giant planets Neptune and Uranus were formed closer to the sun in close proximity to the gas giants, where they were able to gain more mass than in their current orbits.

2. Gravitational interactions between the 4 giant planets pushed Neptune out of close orbit inside Uranus into an eccentric orbit which swept up the planetesimals in the outer disc and driving them out to form the Kuiper belt and Oort cloud

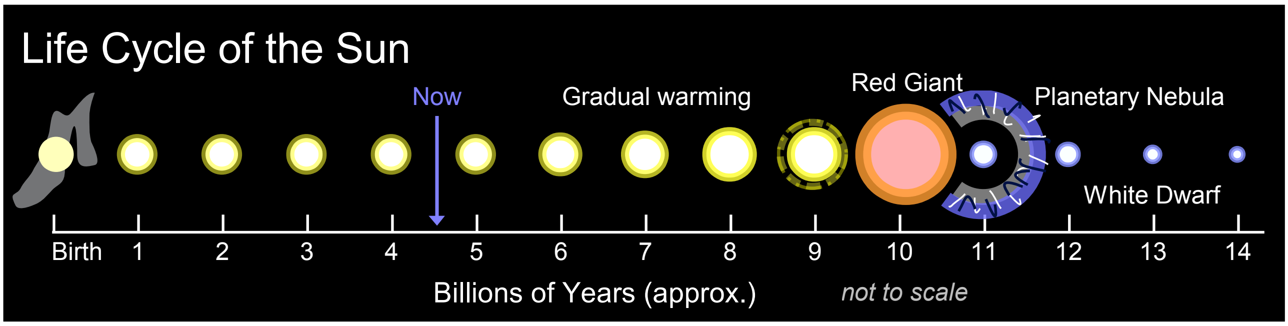
3. Gravitational interactions circularised the orbits in their new locations . Note Uranus also migrated to a new orbit.

1.13 Summary

The described evolution is in my opinion directly related to the following descriptions of the evolution of the earth and its lifeforms. We have progressed from an energetic universe which has been described mathematically but which has not been directly observed. The necessary key steps were H & He nucleosynthesis, stellar evolution, elemental abundance, organic chemistry and planetary formation. The essential outcomes described are certain but some of the processes are theoretical. By the end of this 10 billion years of evolution we have synthesised the elements, and created the stage for life to develop. The view expressed can probably be described as Anthropic, as the Universe described appears fine tuned for human life.

Consider that the most abundant elemants are H, C, O and N which I will show are keys to life and He which is chemically inert, I consider He to be a catalyst or intermediary.

1.14 footnote: The fate of the Sun.



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This short addendum on solar evolution will be referenced through the following chapters.

The Sun is currently 4.6 billion years old, it evolved via the T Tauri phase to the 'Main Sequence as a G class Yellow Dwarf, where it will remain for a further 4-5 billion years. It will eventually go through a relatively short Red Giant stage before core compression ejects the envelope as a Planetary Nebula. The core remnant white dwarf will cool over billions of years.

2. Evolution of the earth
From the LHB to the K/T boundary

2.1 Hell on Earth

The earliest geological period of the earth, was given the name Hadean in 1972, named after the greek god of the underworld. The early Earth had a very high heat flow, a partially molten surface and high volcanic activity, as well as being subject to many collisions. It was totally inimicable to life as we know it. Study of this eon is subject to much research, and our understanding is improving especially with reference to new information from lunar studies The oldest dated rocks come from the end of this eon

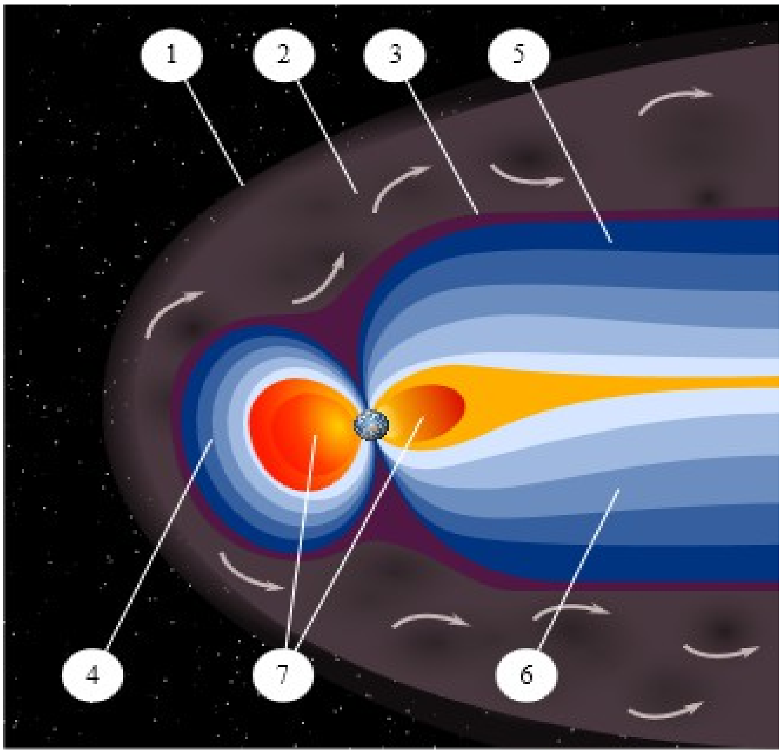
The next geological era thought to start from 4 billion years ago is the Eoarchean era of the Archean eon. It begins with the LHB and the first confirmed crust. It is thought that liquid water existed at the start of this era and that the atmosphere was more dense than now, and consisted mainly of N2 and CO2.

Life may have started in this era, evidence for this includes, kerogen, biogenic graphite and the earliest banded iron formations in rocks from 3.8 to 3.7 billion years ago.

2.2 Planetary differentiation and the 'Iron Catastrophe'

Planetary differentiation, the process by which the materials of the Earth are separated out, chemically, thermally and gravitationally, is thought to have occurred on all bodies in the solar system. For the terrestrial planets which are composed mainly of iron, oxygen, silicon, magnesium, sulphur, nickel, and aluminium, with trace elements including radioactive isotopes, this will have led to an iron core and a mantle and crust composed of silica and metal oxides.

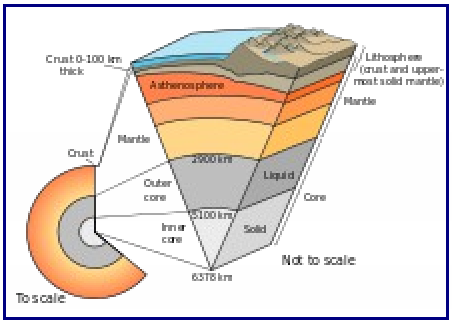
Enhanced heating by the release of gravitational potential energy during this process, the 'Iron Catastrophe theory' would have accelerated the formation of a core of liquid iron. This rapidly rotating iron core would have formed by 4 billion years ago and the resulting magnetic field would have formed the magnetosphere an important step in the early Earth. This would have prevented the atmosphere from being stripped by solar winds and protected the nascent biosphere from high energy radiation.



1 Bow Shock
2 Magnetosheath
3 Magnetopause
4 Magnetosphere
5 Northern Tail Lobes
6 Southern Tail Lobes
7 Plasmasphere

"Magnetosphere Levels" by Magnetosphere_Levels.jpg: Dennis Gallagherderivative work: Frederic MICHEL - Magnetosphere_Levels.jpg. Licensed under Public Domain via Wikimedia Commons -

2.2 Composition and structure of the Earth



Earth cutaway from core to exosphere. Not to scale.

Depth[75] km	Component Layer	Density g/cm^3
0–60	Lithosphere[n 7]	—
0–35	Crust[n 8]	2.2–2.9
35–60	Upper mantle	3.4–4.4
35–2890	Mantle	3.4–5.6
100–700	Asthenosphere	—
2890–5100	Outer core	9.9–12.2
5100–6378	Inner core	12.8–13.1

Planetary differentiation is thought to have quickly separated the earth into its component layers as shown above. The density differences is due to composition, the core being composed of approx 90 % iron and 6 % nickel the densest early period elements. It consists of a solid inner and a molten outer, the Earth's magnetic field results from the dynamo effect caused by the convection and/or rotation of the outer core.

The outer layers are composed of a solid lithosphere and crust floating on a denser plastic mantle, the Earth's inner heat is thought to cause convection in the mantle, which drives a process called plate tectonics. This process drives the continental cratons in a cycle of super continent building and break-up.

The crust is composed of Silica (SiO_2) and other metal oxides, and is approx 47 % oxygen.It is theorised the first supercontinent developed approx 3.6 billion years ago.

2.4 The Hydrosphere

The Hydrosphere has been proposed as a closed system which exists, this system includes all water in lithic reservoirs, soils, oceans, surface fresh water, atmosphere and cryosphere. It migrates between reservoirs in a process call the water cycle, and is one of the basic necessities of life. It plays important roles in the biosphere and the atmosphere, and may have had a pivotal role in the formation of Earth's 'second atmosphere'.

It is thought that Earth's oceans formed as early as 4 billion years ago, from outgassing of crustal water. There are other hypotheses for this including comet impacts and icy asteroids during the late heavy bombardment.

2.5 Earth's second atmosphere.

The original Atmosphere of the earth would have been composed primarily of primordial gases H_2 and He, with traces of volatiles. This early atmosphere would have been removed during the T Tauri phase.

Continued outgassing of volatiles would add H, C, N, O, S and noble gases to the atmosphere, in line with their elemental abundance. During the heating and ejection process these would generally combine chemically and would tend to accumulate more once the magnetosphere had formed. Evidence for outgassing as the primary process of the formation of this atmosphere is the relative abundance of isotope 40 Kr a product of radioactive decay of potassium in the Earth's crust and the primordial 36 Kr.

The accumulation of the gases would tend to depend on their residence times and their molecular composition. The early crust was reducing, so elemental oxygen would readily combine with other volatiles to form CO, CO_2, H_2O and SO_2, H_2 would have escaped space because of its low mass, and would have only remained in the forms H_2O and trace amounts of CH_4, NH_3, H_2S and HCl.

N_2 is highly stable, and would remain in this form with trace amounts of N_2O, NO_2 etc. Finally little or no O_2 would be ejected because of its highly reactive nature. In line with measured quantities in Volcano's today the most abundant gases are H_2O and CO_2.

2.5 Nitrogen dominance

The understood process to account for the dominance of N_2 in this and susbsequent atmospheres is due to the turnover of molecules between source and sink known as residence time. The residence time of N_2 in the current atmosphere is of the order of 16 million years compared with H20 of > 1 day and C02 > 5 yrs. The processes in the early earth were such that similar residence times may have occurred.

Once the earth cooled sufficiently water vapour would have quickly rained out and first shallow seas would have formed, the oceans reaching their present capacity by 4 billion years ago, and a modified hydrological cycle would have been present. There is evidence of sedimentary rocks from 3.8 billion tears ago. The Oceans would have quickly come into balance with water vapour in the atmosphere a process that is solely temperature dependant.

CO_2 has longer residence times, but soon after the oceans formed the terrestrial carbon cycle would have been initiated. Atmospheric CO_2 is absorbed in raindrops and ocean/atmosphere interfaces as carbonic acid, combine in solution and precipitate out as sedimentary carbonate rocks.

As the residence time of N_2 is many orders of magnitude higher than the other components of the atmosphere in can be seen that the atmosphere would quickly reach an equilibrium state of N_2 with CO_2 as a significant fraction, this atmosphere is likely to have an enhanced greenhouse effect.

Finally by approximately 4 billion years ago we have reached a state the Earth's core is mainly atomic Iron and the Earth's atmosphere is mainly Molecular Nitrogen. The Oceans are H_2O and the process of differentiation has mainly stopped with the other elements relatively well mixed in the lithosphere.