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Earth’s first deep breath

The first life on the earth was not oxygen dependent, says S.Ananthanarayanan.

Oxygen first became a major component of the earth’s atmosphere about 2500 million years ago. Abundance of oxygen altered the course of evolution by creating conditions for life, animals and vegetation as we know them.

The course of oxygen build-up in the air and also free oxygen in the oceans has been of vital interest in understanding the evolution of life, as well as the history of our planet. The study is more important in the context of global warming, where the composition of the atmosphere and the sea as a carbon sink are of central interest. The journal ***Natur***e reports this week that Clint Scott and colleagues at the Univ of California at Riverside, California have followed biochemical clues in ancient rocks to trace the evolution of oxygen in the sea.

Oxygen-free world

There is geological evidence that at early times there was scarcely any oxygen in the atmosphere. The oxygen was there, but it was combined, almost all with hydrogen in the form of water, or with other metals, as oxides. While there were bacteria which could perform photosynthesis – extracting oxygen from water (or from CO_2) and forming hydrocarbons, life did not depend on the oxygen released, but consisted of forms that generated methane (CH_4) or other hydrocarbons, and also generated oxygen as a product, rather than make use of oxygen.

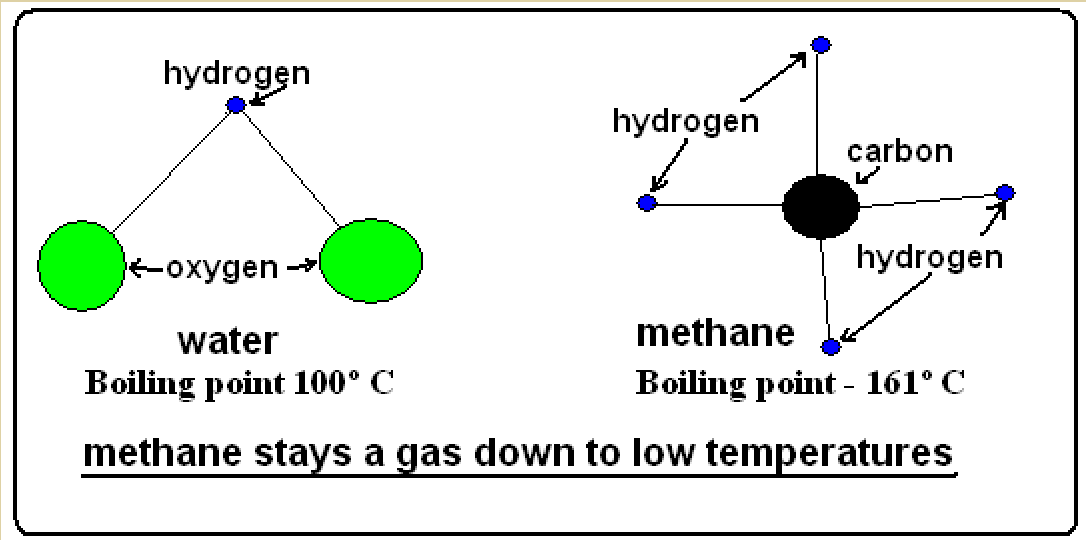
The traditional view had been that the oxygen released by photosynthesis first got used up in combining with metals, to form oxides, or with organic matter, but over a period of time, accumulated in the atmosphere, till oxygen based life could thrive. The problem with this view is that oxygen produced by photosynthesis is always produced along with equal hydrogen or carbon and there is no reason that free oxygen should prefer to be in the air, instead of combining back with hydrogen or carbon.

Enter methane

It was suggested in 2001 that the reason for the carbon in the atmosphere is the work of the methane producing bacteria that abounded around 2500 million years ago.

The thing about water in the atmosphere is that very little water stays as vapour at low temperatures. Thus, for all the water on the surface of the earth, the air at high altitudes, where temperatures are sub-zero, contains very little water vapour. If there were water vapour at high altitudes, the vapour could split into hydrogen and oxygen and the hydrogen, being lighter, could get lost into outer space. But as there is less vapour in the upper atmosphere, such loss of hydrogen is prevented.

This is not the case with methane. Methane stays as vapour down to very low temperatures. It is thus not ‘condensed out’ by the low temperature (-60º C) of the atmosphere at the altitude of about 18 kms. Methane then diffuses past this cold barrier and right up to the very high reaches of the atmosphere. If methane breaks up at these altitudes, the hydrogen component gradually escapes into space and is lost to the earth.



The result of gradual reduction of hydrogen is gradual increase of free oxygen, or oxygenation of the atmosphere. Although this can happen, it first needs the presence of ***methanogens***. Hence, before the ***methanogens*** were there in good numbers, there was no possibility of this happening. But once methane producers got there and the quantity of free oxygen increased, the oxygen itself drew the hydrogen out of methane molecules, and made sure methane itself could not exist in significant quantity. This, in turn, prevented dissociation of high altitude methane and the hydrogen loss, once oxygen was in place, fell back to the low levels as before.

The oxygen rich atmosphere, which appeared from 2500 ago to about 550 million years ago, then set into action the cycle of photosynthesis, hydrocarbons, respiration….. But it is important, to accept this picture, to know how the depths of the oceans were oxygenated over the period to understand how plant and animal life evolved.

New approach

Clint Scot and colleagues investigated the levels of free oxygen in the oceans by examining the content of the metal, molybdenum in rocks formed by sedimentation. Molybdenum has a property of forming a number of oxides and can indicate the abundance or scarcity of oxygen according to the mix of oxides.

Scot et al found that the molybdenum entering sediments was only mildly oxidized before about 2200 million years ago. Oxidation became more vigorous in about 50 million years, or about 200 million years after the oxygen content of the atmosphere first began to grow. By the time of about 550 million years ago, the deep oceans had got oxygenated and modern biochemical cycles got established. Which Led to the appearance of larger animals and the course of evolution that followed.