Re: Snowball Earth at 2.3 gya

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- *From*: "Perplexed in Peoria" <jimmenegay@xxxxxxxxxxxxx>
- *Date*: Sun, 14 Aug 2005 19:26:34 −0400 (EDT)

"yahooterry@xxxxxxxxx" <terryhilleman@xxxxxxxxxxx> wrote in message
news:ddmh11$1bob$1@xxxxxxxxxxxxxxxxxxxxxxx
> This is just my opinion, but with an early−earth atmosphere similar to
> Jupiter, methane was likely the primary atmospheric greenhouse gas (25X
> as potent as CO2), keeping water in liquid form at this time of lower
> sun intensity. Methane and ammonia seem to be stable on Jupiter and
> the other gas giants, in spite of the storms on the surface.

But that first primary Earth atmosphere of H2, methane, and ammonia would have been blasted into space by the impact which created the moon; then blown away by the solar wind. Earth then acquired a "secondary atmosphere" by outgassing which was far more oxidizing. The secondary atmosphere consisted primarily of H2O, CO2, and N2. There may have been traces of H2, methane, and ammonia, but it is probable that C02 was the primary greenhouse gas. At least that is the story as I heard it.

> Free
> oxygen, produced (by cyanobacteria like the today's top producer,
> Prochlorococcus marinus) would have first rusted iron in surrounding
> seas; oxygen was not at all initially abundant. As iron went out of
> solution, the oxygen could then be free to act on aqueous sulfates,
> atmospheric ammonia and atmospheric methane.

I think that it is far more likely that the first photosynthesizers did not produce free oxygen − that they oxidized iron, sulfur, and nitrogen directly. Oxygenic photosynthesis probably did not arise until oceanic stores of ferrous iron and H2S were nearly depleted and the only available was H20.

The way you describe it, with the oxidation of iron and sulfur being a geochemical process rather than a biological one, may well have become important once oxygenic photosynthesizers arose. So the neoproteroic red beds (0.7 − 0.6 gya) may have resulted from the process you describe. But I believe that most earlier iron deposites (magnetite and pyrite) were produced by direct biological action.

> Atmospheric nitrogen and

> carbon dioxide resulted; had it not been for life locking−up CO2, we
> would have a CO2 atmosphere like Mars and Venus. There was likely
> insufficient CO2 in the atmosphere to prevent the snowball of 2.3bya.,
> once a necessary amount of methane was lost to oxidation (to CO2).
> Small amounts of CO2 (O2 from photolysis of H2O) would be necessary for
> photosynthesis to produce the oxygen, but todays historical planatary
> low CO2 levels provide more than enough CO2 for the process.

My understanding is that the primary source of CO2 for the early
atmosphere was outgassing, rather than oxidation of methane by
atmospheric OH radicals after photolysis of water. Though I do
agree that the process of CO2 production that you describe would have
occured, and would have kept the atmospheric methane levels fairly
low.

> Photosynthesis is likely a chemosynthetic bacteria variation of the
> following similar processes, one of which is an anaerobic
> photosynthetic depletor of atmospheric CO2..
> Careful examination at ground level reveals a green bacterial layer at
> or just below the moist surface (photosynthesis occurs here). Below
> the green layer is a red layer (of sulfate fixing bacteria); this is an
> area of sulfate (and nitrate) formation via oxidation. Further below
> the red layer is a black layer (of sulfide bacteria); this is an area
> of sulfate reduction. Hydrogen sulfide (H2S) production occurs here.
> A similar community exists under ponds, lakes and oceans. The
> near−surface green layer is in the water column above. Sometimes the
> sulfate−fixing cloud of bacteria can be seen floating in oxygenated
> water just above the bottom floor. In the bottom black sulfide layer,
> smelly, toxic, hydrogen sulfide (H2S) is produced. This black layer
> can also contain inorganic carbon as carbon dioxide (CO2) and
> anaerobically locked−up carbon as methane (CH4). Sulphur compounds,
> mainly hydrogen sulphide (H2S), can serve as sources of electrons for
> bacterial chemosynthesis. As in photosynthesis, inorganic carbon (CO2)
> is reduced to organic carbon (CH4), while the oxidation of sulphur
> serves as the source of energy instead of light. This oxidation may go
> all the way to sulphate (SO4=) by the acid−producing (sulphur) bacteria
> or may stop at an intermediate oxidation state. In other words,
> chemobacteria can create carbohydrates capturing close−by carbon in a
> chemosynthetic cousin of the carbon cycle. The sulfate produced can be
> reduced once again by sulfate−reducing bacteria, providing additional
> energy.
> Chemosynthetic bacteria obtain energy by chemical oxidation or
> reduction of simple organic compounds. Examples include NH3 to N2 or
> (NO2−) or (NO3−), or to (NH4+); H2S to S or (SO3=) or (SO4=), or, vice
> versa; and FeS2 to Fe(OH)3, (SO4=) & H+, as well as Fe2O3 and H2S to
> FeS2. Oxygen must be present in the environment for oxidation to
> occur. There are exceptions. Black sulfide layer activity has been
> recently discussed (chemobacteria can create carbohydrates capturing
> close−by carbon in a chemosynthetic cousin of the carbon cycle).
> Anaerobic photosynthetic sulphide oxidation occurs primarily in
> estuaries.

The kind of "Winogradsky column" organization that you describe only
makes sense if there is a source of free oxygen at the top of the
column and a source of reduced organics at the bottom. It strikes
me as unlikely that the mechanisms of photosynthesis would arise
from such an ecosystem. It strikes me as much more likely that the
chemosynthetic mechanisms of that column ecosystem arose from the
sequence of primitive photosynthetic mechanisms, as they developed
to oxidize first iron and sulfur, and finally water.

> Jannasch, H. W., in Interactions between the Carbon and Sulphur Cycles
> in the Marine Environment, has an interesting perspective. Since
> hydrogen sulphide is a product of sulphate reduction and that uses
> photosynthetically−produced organic matter as reductant, chemosynthesis
> by sulphur−oxidizing bacteria could be considered in the flow of energy
> as a form of secondary production. Microbial sulphur oxidation appears
> twice. It appears 1st as an aerobic and chemosynthetic process. It
> appears 2nd as an anaerobic photosynthetic process. In estuaries,
> bacterial anaerobic reduction of CO2 requires light as a source of
> energy and uses hydrogen sulphide (H2S) as a source of electrons. In a
> way, if the above terminology is used, this bacterial photosynthesis
> represents (as does the green plant photosynthesis) a form of primary
> production. Green plant photosynthesis uses H2O rather than H2S for
> the electron source. The distinction between primary and secondary
> production of organic carbon is important if the interactions between
> the carbon and sulphur cycle are linked to the flow of energy, be it
> light or chemical energy.
> Mid−ocean rift sea−vent chemobacteria extremophiles mimic activities of
> their photosynthetic cousins from above, making carbohydrates from
> H/O/C; they can create carbohydrates (e.g. CH4) capturing close−by
> carbon in a chemosynthetic cousin of the carbon cycle. Recall that
> reduced sulphur compounds, mainly hydrogen sulphide (H2S), can serve as
> sources of electrons for bacterial chemosynthesis. As in
> photosynthesis, the presence of inorganic carbon permits reduction to
> organic carbon while the oxidation of sulphur serves as the source of
> energy instead of light. This oxidation may go all the way to sulphate
> by the acid−producing (sulphur) bacteria or may stop at an intermediate
> oxidation state.

ISTM that it almost HAS TO stop at an intermediate oxidation state if
you want to extract energy from the process and don't have a photo−assist
or an oxidizer stronger than CO2.

> Other types of sea vent extremophiles simply use
> sulfate reduction (to sulfides) for respiration; both parallel
> chemosynthetic activity seen in the bottom of the green−red−black
> surface layers.
> In addition, chemobacteria extremophiles in sea vents and non−marine
> hot springs (both at very high temperature) can use locally−abundant
> sulfur (S), rather than oxygen, as an electron acceptor in respiration.
> In this case the reduction of sulfur generates hydrogen sulfide (H2S)

> rather than water, as a by−product of respiration. This can be used by
> other extremophiles (recall the mid−ocean rift, in the area of the
> under−water hot water cycle, can contain certain chemobacteria capable
> of creating carbohydrates capturing close−by carbon in a chemosynthetic
> cousin of the carbon cycle). If the available sulfur is organically
> bound, the sea vent / hot spring extremophiles may produce hydrogen
> gas, which is of use to still other extremophiles (deep−rock
> extremophile discussion follows). Sea−vent/hot−spring extremophiles
> are often anaerobic, but can tolerate oxygen to some degree. Their
> ability to generate hydrogen from organic waste products, while
> tolerating oxygen allows great flexibility.
> Chemobacteria extremophiles can have many different pathways for their
> very slow respiration. Chemobacteria extremophiles that live deep in
> the earth only need water to live in and heat of the earth (energy) to
> reduce (or oxidize) rocks and minerals. H2 gas is released as water
> seeps through rock (produced from iron oxide reacting with water);
> molecular hydrogen can be reacted with carbon, oxygen or sulfur to
> sustain deep rock extremophile respiration. In caves, extremophile
> (sulfur) bacteria derive their energy from inorganic hydrogen sulfide;
> previously discussed, H2S is carbohydrate−convertible when small
> amounts of carbon are present (chemobacteria can create carbohydrates
> capturing close−by carbon in a chemosynthetic cousin of the carbon
> cycle). Limestone extremophiles can reduce the rock and release CO2;
> the resultant carbonic acid dissolves limestone, forming caves.

You have given a long recitation of the variety of energetic and redox
processes in the microbial world. At the risk of seeming impolite, I
have to ask, was there a point to this presentation? If there was an
argument buried in all those facts, I'm afraid I have lost sight of it.

> As far as the Pre−cambrian snowballs go, there enough increased sun
> intensity for CO2 levels to now play a major role.

Huh? Are you simply saying that the sun is hotter now than it used to
be, so we don't need methane anymore? That CO2 suffices? Well, yes,
but that can't be the whole story. The sun was presumably cooler during
the snowball−free period of 2.2−0.8 gya than it was during the snowballs
of the neo−proterozoic 0.8−0.6 gya. What triggered the neoproterozoic
snowballs. This web site:
http://www−eps.harvard.edu/people/faculty/hoffman/snowball_paper.html
suggests that plate tectonics had happened to place most of the
continents near the equator during the late neoproterozoic. Apparently
when there are continents at higher latitudes, glaciation of those
continents slows the carbonate/silicate weathering cycle, thus reducing
the rate of geochemical removal of CO2 from the atmosphere. But with
most continents near the equator, the icecap continues to move south
and the CO2 removal process doesn't shut down until too late.

> Unicellular plant
> life dropped atmospheric CO2 enough to create the smowballs; there was
> likely no total blackout. Anyone that has spent much time diving under

> ice realizes that there is only a die−back for plant life, and it is
> not that dramatic. There may have even been open water.

Yes, there is some evidence that the neoproterozoic snowballs did not all completely cover the oceans with ice. But the paleoproterozoic snowball (2.3 gya) is claimed to have been more severe. Even so, life could survive, and not just at deep sea vents. There are photosynthetic bacteria in the dry valleys of antarctica. There are continental hot springs, like Yellowstone. There are spreading vents above sea level, like Iceland. And there are non−continental hot−spot volcanoes like Hawaii. You are correct to call it a die−back. But it is also probably a mass extinction. Some whole chemosynthetic processes and lifestyles may have been lost with their extinguished practitioners.

> The dual−role
> bacteria have an even greater ecological valance than the
> cyanobacteria. Primitive life at the equator was never really
> threatened.
>
> I would not date the last universal common ancestor to the 1st
> snowball, even though the environment certainly selected for life
> changes. Primitive life had endured far greater challenges. It was
> not as yet even an oxygenating environment; only small quantities were
> released at one time. It seems to me that the Ediacaran biodiversity
> following the worldwide last Precambrian (Varangian) glaciation
> parallels the planet of the apes situation of 8−10 mya., where there
> were many candidates for our ancestor, which were a result of a
> previous adaptive radiation.

I'm afraid you lost me here. Your first two sentences seem to say that the LUCA was likely earlier than 2.3 gya, contrary to my suggestion. Well, Ok. But then you confuse me by talking about Edicaran diversity and the planet of the apes. There were many branches to the hominid tree. All but one of them died out, but that was not due to an environmental catastrophe. Are you cautioning me not to see snowballs and similar catastrophes as the ONLY processes capable of pruning the tree of life? If so, your point is taken.

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- ***References***:
    - ***Snowball Earth at 2.3 gya***
        - *From:* Perplexed in Peoria
    - ***Re: Snowball Earth at 2.3 gya***
        - *From:* yahooterry@xxxxxxxxx

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