Snowball Earth

by Herb Windolf
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In the 1920s the German meteorologist Alfred Wegener introduced the idea of Continental Drift. He primarily based his theory on the apparent fit of the west-African coast with that of South America. Because he did not have a background as a geologist or geophysicist, he did not offer an explanation as to how continents could drift across the face of the Earth. Without substantial evidence, and because no mechanism was known at the time, his ideas were not taken seriously. It would be another 40 years before his idea of continental drift would be accepted. In the early 1960s scientists discovered the mid-Atlantic ridge and its related volcanic activity. It was now possible to measure the plate motion as it pushed crust in both eastward and westward direction from the ridge.

Today science readily accepts the concept of Continental Drift or tectonic plate movement, and the same may likely happen with the hypothesis of “Snowball Earth”. Joe Kirschvink of Cal Tech coined the term “Snowball Earth”, but like Wegener he did not pursue his idea. Kirschvink was not referring to the “minor” recurring ice ages like the most recent one terminating only 10,000 years ago, but one of entirely different origin. In the 1930s a British geologist presented the outline of a great infra-Cambrian ice age, but he did not have the evidence to support it. Support for his theory did not come forth until the 1980s when a CalTech scientist discovered evidence that ice had reached the equator in Precambrian times. Still, only a few scientists entertained the idea that the entire Earth could have frozen. Most scientist held the opinion that the reflection of sunlight from this global ice sheet would prevent its melting and the Earth would remain a perpetual ice ball. In 1992 Kirschvink countered his opponents with a brilliant solution for this conundrum. He proposed that several major volcanic outbreaks contributed to the melting of the ice sheet! He suggested that this phenomenon could have occurred several times about 700 million years ago. Kirschvink’s theory envisions multiple ice advances, extending all the way to the equator, being interspersed with periods of volcanic melting.

Why did this happen? Kirschvink suggested that from time to time tectonic plate movement concentrated most of the continents near or at the equator. While located near the poles the darker land masses absorbed a great deal of solar heat and prevented ice from creeping southward. Once land became concentrated nearer the equator, ice slush would have congealed in the polar oceans, eventually forming thicker and thicker sheets. A cloud-free sky with little if any snow fall would have occurred and the average temperature could have dropped to -40º Celsius.

In Iceland, scientists have observed the eruption of sub-glacial volcanoes. As they erupt they release large amounts of CO_2. Carbon dioxide, a greenhouse gas, permits sunlight to enter the atmosphere, but it prevents subsequent infrared radiation from escaping into space. After millions of years the accumulation of CO_2 in the atmosphere produced a rise in the average global temperature initiating a major melting event. Some scientist believe that the melting could have occurred within just a few hundred years. Average temperatures may have soared to +40º Celsius. In addition, frequent hurricanes could have produced torrential acid rain all over the planet.

To gain support for his theory, Kirschvink mentioned his ‘Snowball Earth’ idea to Harvard geologist Paul Hoffman who then took up the pursuit. In Namibia, later in many other places where Precambrian rock was exposed, he found a layer of carbonate rock immediately above a thick layer of pebbles and boulders, called drop stones. These drop stones are believed to be glacial till transported by icebergs. After calving from the main ice sheet, icebergs float out to sea and gradually melt, dropping their accumulated till onto the ocean floor. Found immediately above the till deposit is a layer of carbonate rock. Carbonate rocks usually form at the bottom of warm, shallow seas, which would support the idea of either global warming or an equatorial position.

Another possible explanation for this till/carbonate relationship came from a Harvard geologist. He suggested that torrential acid rains fell onto accumulated layers of dust, glacial "rock flour" produced in millions of years of glacial grinding. This dust and acid rain combination was washed into the seas creating, what he described as a fizzing and foaming "Coca Cola" ocean. The dissolved CO_2/dust mixture turned the seas milky white and initiated the chemical precipitation process that produced the carbonate rock layers found above the "drop stone" layer.

What would have been the effects on life? It is thought that life appeared on Earth within the first 500 million years after its formation. Over the next 3 billion years, mainly single-celled organisms and blue-green algae populated the world’s oceans as slimy algal mats, while other extremophile forms could be found in rocks and around underwater thermal vents. Curiously enough, multi-cellular life arose about one billion years ago, not much before the predicted time of the last "Snowball" event. Could there be a connection?

The early Earth’s atmosphere was rich in CO_2, but had relatively little oxygen. A large increase in oxygen levels is directly related to the respiration process associated with life. Oxygen is a basic requirement for animal life. The increased abundance of oxygen in the atmosphere by 550 million years ago could have served as a stimulant for the rise of multi-cellular organisms, cumulating in the Cambrian life explosion. In addition, it is suggested that the nutrients, which enriched the oceans during the "Snowball Earth" periods are thought to have provided food for the rapidly evolving life forms.

The extinction of many life forms in the course of the global glaciations is certain, but some would have survived. Research in Antarctica has shown that light does filter through the top layers of clear glacial ice and through pack ice to the shallow sea bottom. This would permit a certain amount of photosynthesis to take place. Pockets of life would also have persisted near volcanoes on land and near submarine vents to permit the continuation of the more basic life forms.

In conclusion, Kirschvink's theory of "Snowball Earth" offers a fascinating addition to the results of tectonic plate movement and its effects on life. Just as the end of the last ice age and the subsequent relatively stable world temperatures made possible the rise of human civilization, so the post-Snowball Earth conditions may have been conducive to the rise of life, the evolution of higher life forms on the planet we know today.

"Snowball Earth: The Story of the Great Global Catastrophe that spawned Life as we know it", by Gabrielle Walker, Ph.D., is a thought-provoking book for additional reading.