

Once Upon a Time in the Arabian Sea

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Carbon dioxide is a greenhouse gas majorly responsible for global warming in recent years. Its concentration in earth's atmosphere has been fluctuating for several thousands of years in the fluctuations can be observed by studying the past, and future variations can be predicted. Carbon dioxide gas in the earth's atmosphere is taken up by the ocean when its pressure is less in seawater than in the atmosphere. Carbon dioxide dissolves in sea water and forms two main components bicarbonate ion (chemical formula HCO_3^-) and carbonate ion (chemical formula CO_3^{2-}). The carbonate ion and calcium from sea utilised by some calcareous organisms in seawater to make its hard parts such as shells which are made out of calcium carbonate. When these organisms die their shell sinks to the bottom of sea and remains untouched and preserved for several thousands and millions of years. In other words these organisms capture the carbon (in the form of carbonate ion) from sea water in their shell during shell formation and preserve it for a very long time. Through the chemical analysis of these shells one can understand the change in carbon, carbonate ion and subsequently carbon dioxide in seawater as well as in atmosphere which happened several years ago.

Similar work was conducted at our laboratory at CSIR-National Institute of Oceanography, Goa, by studying sediment samples dated till 25000 years. The 25000 years are generally classified by scientists into cold and; they are, the Last Glacial Maximum (LGM), from 24000 to 18000 years which was a cold period and the deglaciation from 17500 to 10000 years wherein warming took place, and the Holocene, a warm 0000 years to present. The colder and the warmer climate of these periods are mainly controlled by carbon dioxide (greenhouse gas) in the atmosphere. During LGM,

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carbon dioxide gas was 180 ppmv which resulted in less greenhouse effect and cooler climate the Holocene period it was 280ppmv contributing to more greenhouse effect and warmer climate. But the mystery is that that how carbon dioxide which was low during the LGM suddenly increased during Holocene? Well the answer must lie somewhere in the deglacial period.

We chemically analysed foraminifera (microscopic organism) shells from core

From the Arabian Sea and dated till 25000years. Shells were chemically analysed for their elemental content i.e. Boron (B) and Calcium (Ca), the elements of interest their concentration is measured and ratio taken (B/Ca ratio). The concentration of boron in seawater increases with increase in pH. If seawater has high pH then boron content increases and more amount of boron is taken up by foraminifera in its shell. Hence through B/Ca ratio, pH of seawater can be calculated. The pH of seawater is again related to carbonate ion concentration in seawater and thus, carbonate ion concentration can be calculated from pH and carbon dioxide changes in seawater can be predicted. In this study we used organisms that spend their entire life at the bottom of the sea and hence, tracked and captured the bottom water conditions. The work was carried out at the Rutgers University in New Jersey, USA. The measured B/Ca ratios were then converted to carbonate ion concentration by an equation given by well-known UK scientists Yu and Elderfield from University of Cambridge in 2007. Calculated carbonate ion concentration values when plotted with their respective age, higher concentrations were observed during deglaciation and lower concentrations were observed during LGM and Holocene in deep waters.

Higher concentration of carbonate ion in deep waters signifies lower concentration of carbon dioxide in it because as the carbon dioxide concentration in seawater increases the concentration of carbonate ion decreases and vice versa. Although carbonate ion is formed from dissolution of carbon dioxide in sea increase or decrease in quantity of these two parameters are inversely dependent on each other. So higher carbonate ion concentration signifies lower carbon dioxide and lower carbonate ion signifies higher carbon dioxide in deep waters. We observed a lower carbonate during the LGM in deep waters which means there lies the higher carbon dioxide in deep waters then interpreted that the carbon dioxide from atmosphere was taken up and stored in deep waters of the World resulted in lower carbon dioxide in atmosphere during the LGM time and hence, resulted in cooler climate. Higher carbonate ion concentration was observed in sea to lower carbon dioxide in deep waters, which means that the carbon dioxide which was stored in deep waters during the LGM was given out to atmosphere during deglaciation and resulted in sudden global increase in carbon dioxide in atmosphere just after the LGM.

Various scientists from all over the world working on this issue state that during deglaciation the westerlies (winds that blow from west to east between 30-60°S latitude) shifted southward in Southern Ocean and resulted in diverging movement of surface water and upward movement of deep water which exposed deep carbon dioxide from it moved into intermediate waters. These deep and intermediate waters then travelled to all the major oceans of the world and carbon dioxide from intermediate waters was passed on to surface waters of these oceans and then given out to atmosphere resulting in global carbon dioxide increase during deglaciation.

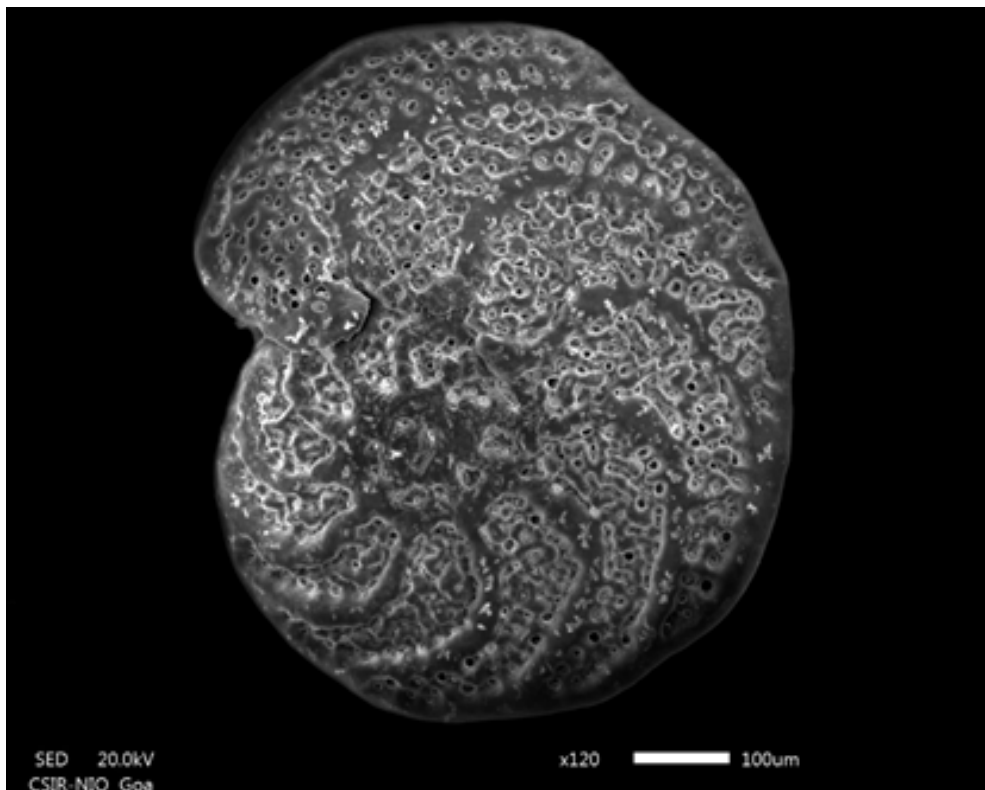


Figure: SEM image of foraminifera shell (*Cibicoideswuellerstorfi*) used for B/Ca analysis.

Our study, carried out in deep waters of the Arabian Sea showed higher carbonate ion concentration which signify lower carbon dioxide. Lowering of carbon dioxide must have occurred through its movement in the intermediate waters. A study in Arabian Sea carried out by Sean Bryan and his group in the University of Colorado, USA, in 2010 showed depletion of ^{14}C in intermediate waters by lighter carbon which must have originated from deep waters and also higher pressure of carbon dioxide gas was observed in surface waters of Arabian Sea by Sushant Naik and his group at the CSIR-National Institute of Oceanography, Goa, in 2015 during deglaciation which was released to the atmosphere. So this makes us conclude that once upon a time in the Arabian Sea during deglaciation, its deep waters released carbon dioxide which first travelled through its intermediate waters then to its surface waters and finally made its way in to the atmosphere and contributed to the sudden global rise of carbon dioxide during deglaciation.