Climate Change, Oceans, and Human Health

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INTRODUCTION

Since 1800, atmospheric CO_2 concentrations have increased from roughly 280 parts per million by volume (ppmv) to 380 ppmv, primarily as a result of fossil fuel burning and deforestation. Projections by the Intergovernmental Panel on Climate Change indicate that these concentrations will increase to about 710 ppmv by 2100. Environmental impacts associated with this increase in atmospheric CO_2 include a lowering of seawater pH, an increase in average surface air temperature (1.4–5.8 °C) and sea surface temperature (2–3 °C), changes in meridional temperature gradients and associated wind systems, increased thermal stratification of the water column, poleward expansion of tropical/subtropical weather systems, increases in evaporation rates, and changes in precipitation patterns.

There is widespread concern over the impacts these environmental changes will have on the Earth's ecosystem and on human societies. The concern stems in large part from the very rapid timeframe of the changes. Over geologic time the climate of the Earth has in fact changed dramatically. Despite geological evidence for oxygen-producing photosynthesis as early as 3.5 billion years ago,[1] the Earth's atmosphere appears to have remained devoid of oxygen for roughly another 1.5 billion years. Most of the oxygen produced by photosynthetic processes was apparently consumed by reactions with (primarily) ferrous iron and (secondarily) sulfide in seawater.[2] Following this so-called rusting of the oceans it was possible for oxygen to diffuse into the atmosphere, but atmospheric O_2

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1. For example, widespread deposits of Banded Iron Formations.
2. W.H. Schlesinger, *Biogeochemistry: An Analysis of Global Change* (San Diego: Academic Press, 1997).

Ocean Yearbook 21: 129–175.

concentrations comparable to present values (21 percent) were probably not reached until the Silurian, roughly 430 million years ago. Initially much of the oxygen released to the atmosphere was apparently consumed by reactions with reduced minerals such as pyrite (FeS_2), resulting in fluvial transfer of Fe_2O_3 to the ocean. This process of terrestrial weathering is evidenced by the accumulation of the so-called Red Beds, deposits of Fe_2O_3 alternating with layers of other lithogenous sediments. Consistent with this scenario is the fact that the earliest occurrence of Red Beds roughly coincides with the latest Banded Iron Formation deposits.[3]

There is good reason to believe that atmospheric O_2 levels have not fluctuated outside the 15–35 percent range since the Silurian.[4] At O_2 concentrations less than 15 percent fires would not burn,[5] and at concentrations greater than about 25 percent even wet organic matter would burn freely.[6] The principal mechanism responsible for the stability of atmospheric O_2 concentrations appears to be the negative feedback between O_2 concentrations and the long-term burial of organic matter in sedimentary rocks.[7]

Particularly noteworthy from the standpoint of current global climate change issues is the fact that atmospheric CO_2 concentrations during Phanerozoic time (approximately the last 570 million years) have generally been higher than current values, perhaps by as much as a factor of 20–25 during the Cambrian.[8] The impact of these elevated CO_2 concentrations on the climate of the Earth has been profound (Figure 1). Since the formation of the solar system the luminosity of the Sun has increased by about 43 percent, a result of the Sun's slow expansion associated with the conversion of hydrogen to helium in its core.[9] In the absence of greenhouse gases to trap infrared radiation, the Earth would have been fully glaciated until roughly 1 billion years ago, but geological evidence indicates that there has been abundant liquid water on the Earth's surface for more than 3 billion years.[10] Ammonia may have accounted for much of the greenhouse effect in

3. *Id.*

4. R.A. Berner and D.E. Canfield, "A New Model for Atmospheric Oxygen over Phanerozoic Time," *American Journal of Science* 289 (1989): 333–361.

5. J.E. Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 1979).

6. A.J. Watson, "Methanogenesis, Fires, and the Regulation of Atmospheric Oxygen," *Biosystems* 10 (1978): 293–298.

7. Schlesinger, see n. 2 above.

8. R.A. Berner and Z. Kothavala, "Geocarb III: A Revised Model of Atmospheric CO_2 over Phanerozoic Time," *American Journal of Science* 301 (2001): 182–204.

9. C. Sagan and C. Chyba, "The Early Faint Sun Paradox: Organic Shielding of Ultraviolet-Labile Greenhouse Gases," *Science (NY)* 276 (1997): 1217–1221.

10. *Id.*