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Geochemical constraints on the partial pressure of carbon dioxide in the Archaean atmosphere from Banded Iron Formations

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There is geological evidence from the widespread preservation of waterlain sediments that Earth's climate resembled the present during the Archean, despite a much lower solar luminosity. This was cast as a paradox by Sagan and Mullen in 1972. Kasting (1993) suggested a solution to the paradox by increased mixing ratios of greenhouse gasses, notably CO2 in the early atmosphere. However geochemical evidence for high partial pressures of CO2 are absent in marine sediments as well as in paleosols. We have used banded iron formation (BIF) to characterize the composition of the atmosphere. BIFs originated as chemical sediments precipitated from the Archaean ocean and sedimented as particles to the seafloor. Magnetite is ubiquitous in Archaean BIFs which indicates that it was thermodynamically stable during exposure of the primary sediment to ocean water and during subsequent diagenesis and compaction of the sediment. The involvement of biologic processes in the original precipitation of iron-rich minerals and/or sediment diagenesis does not alter the constraint of magnetite saturation. The stability relations of magnetite preclude CO2 mixing ratios much higher than the present atmospheric level (~3-5 times PAL). At higher partial pressures of CO2 siderite would replace magnetite as the stable iron bearing phase. The CO2 pressure of the atmosphere is expressed in the CO2 concentration of seawater through the water column and well into the sediment because CO2 is highly soluble in water. In the absence of substantial compensation for the lower solar irradiance by greenhouse gasses in the atmosphere, we have examined the factors that controlled Earth's albedo. These are primarily the surface albedo of Earth and the abundance and properties of clouds. We have applied a model that takes into account the apparent growth of Earth continents (Collerson and Kamber 1999) and the absence of land vegetation during the Precambrian for the evolution of the surface albedo, and a model for the abundance and properties of clouds that takes into account the lower abundance of biogenic cloud condensation nuclei in a less productive prokaryotic world. The higher transparency of the atmosphere for short wave incoming solar radiation and the lower surface albedo on an early Earth dominated by oceans, provided significant compensation for the lower solar irradiance which allow the presence of liquid oceans, even at greenhouse gas concentrations broadly similar to the present day values.

We therefore suggest that the thermostasis during Earth geologic record, is not paradoxical, but is the combined effect of many factors, which are to a large part biologically controlled.

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