THEME 6: THE EARLY EARTH AND PLANETS

Session 6.5: Early atmosphere

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This session solicits papers that present new experimental data, modeling results and observational constraints on the Hadean, Archean and Proterozoic atmosphere. The composition and climate of the early terrestrial atmosphere are important parameters that affect theories for the emergence and early evolution of life. Emphasis will be placed on theoretical and observational studies that provide constraints on greenhouse gas (e.g. CO_2, CH_4, SO_2, H_2O) concentrations and the changing redox state of Precambrian atmospheres with time. Fundamental problems to be discussed include: Noble gases in the context of the origin of the Earth's atmosphere (timing, loss and change), mass independent isotope fractionations (O, S) observed in the geochemical record, Paleoproterozoic carbon isotope excursions and their application to tracing changes in the geochemical carbon cycle, composition of volcanic emissions in Archean and Proterozoic, hydrogen escape, geological constraints on paleo-temperature, the history of atmospheric oxygenation and the appearance of an atmospheric UV-shield.

6.5.11

Geologic evidence for evolution of the Archean atmosphere

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Accumulating geological evidence suggests that before about 3.1 Ga the Earth's climate was controlled by a greenhouse in which atmospheric pCO_2 was at least 100-1000 times present levels and perhaps as high as several bars. Cherts representing sediments deposited under normal, open marine conditions, unrelated to hydrothermal vents or exhalites, show oxygen isotopic compositions indicating surface temperatures of 70±15°C [1]. Sodium bicarbonate or nahcolite ($NaHCO_3$), which is not deposited at the surface today because of low atmospheric pCO_2, accumulated widely as a primary evaporitic sediment [2,3]. First-cycle conglomerates, sandstones, and shales show mature, fractionated compositions, pointing to an aggressive weathering regime even in the absence of land vegetation [4,5]. High surface temperatures were probably regulated by a mixed CH_4/CO_2 greenhouse in which $CH_4/CO_2 \ll 1$, preventing formation of an organic haze. The formation and weathering of large blocks of new continental crust 3.2-3.0 Ga led to gradual depletion of atmospheric CO_2. By 2.9-2.7 Ga, declining pCO_2 resulted in climatic cooling, glaciation, and siderite-free soils. Transient CH_4/CO_2 ~1 resulted in the sporadic formation of organic haze, reflected in global deposition of abnormally ^{13}C-depleted organic C. Eventual lowering of continental blocks by erosion, consequent reduced CO_2 loss by weathering, and continued long-term tectonic recycling resulted in rising pCO_2 and decreasing CH_4/CO_2 levels in the later Archean and eventual re-establishment of a mainly CO_2 greenhouse. A similar cycle may have characterized the latest Archean and early Proterozoic, but rising production of O_2 at this time maintained $CH_4/CO_2 \ll 1$.

This work was supported by NASA Exobiology Program Grants NAG5-98421 and NAG5-13442 to DRL and a William R. and Sara Hart Kimball Stanford Graduate Fellowship and by a Harvey Fellowship to MMT.

References

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