A fractal aggregate model of Early Earth organic hazes: UV shielding with minimal antigreenhouse cooling

E.T. WOLF[1,2]*, F. TIAN[1] AND O.B. TOON[1,2]

[1]Laboratory for Atmospheric and Space Physics, University of Colorado, UCB 392, Boulder, CO 80309
(*correspondence: eric.wolf@colorado.edu)
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado

The Archean Earth (3.8 to 2.5 billion years ago) was probably enshrouded by a Titan-like photochemical haze composed of fractal aggregate hydrocarbon aerosols. In this study a three-dimensional fractal aggregate model of the early Earth photochemical haze is explored and compared with the standard liquid drop haze model used in earlier studies [1]. Fractal aggregate microphysical processes are modeled using the method introduced by Cabane *et al.* [2]. The optical properties of the aerosols are determined using a mean-field approximation of multiple scattering by fractal aggregates composed of identical spheres [3]. Early Earth fractal hazes are found to be optically thick in the ultraviolet wavelengths while remaining relatively transparent in the mid-visible wavelengths. At an annual production rate of 10^{14} grams per year and an average monomer radius of 50 nanometers, the haze has global mean effective optical depths of $\tau_{uv} = 11.2$ and $\tau_{vis} = 0.5$. Such a haze would provide a strong shield against UV light while causing only minimal antigreenhouse cooling. Protected by a strong UV shield, photolytically unstable greenhouse gases such as CH_4 and NH_3 may have been able to build up to high concentrations helping warm the young Earth despite the faint young Sun. Our findings reopen the hypothesis of Sagan and Mullen [4] that the young Earth may have been home to a reducing atmosphere.

[1] J.D. Haqq-Misra *et al.* (2008) *Astrobiology* **8(6)**, 1127. [2] M. Cabane *et al.* (1993) *Planet. Space Sci.* **41(4)**, 257. [3] R. Botet *et al.* (1997) *Applied Optics* **36(33)**, 8791 [4] C. Sagan, G. Mullen (1972) *Science* **177**, 52.

Magma physical properties affect isotope variations in volcanic rocks: The example of high-T rhyolites

J.A. WOLFF*[1], B.S. ELLIS[1] AND F.C. RAMOS[2]

[1]School of Earth and Environmental Sciences, Washington State University, Pullman, WA 99164, USA
(*correspondence: jawolff@mail.wsu.edu)
[2]Dept. of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, USA

Volcanic rocks often exhibit internal heterogeneity in radiogenic isotopes. Isotopic disequilibrium between co-existing phenocrysts, phenocrysts and matrix, and isotopic zoning within single crystals ("crystal isotope stratigraphy") has been demonstrated in basalts, andesites, dacites, rhyolites and alkaline magmas. High-temperature "Snake River type" rhyolites appear to be an exception. Despite the occurrence of Snake River Plain rhyolites in a region of isotopically highly variable crust and mantle, and significant differences from rhyolite unit to rhyolite unit, internally they are near-homogeneous in $^{87}Sr/^{86}Sr$. Little or no zoning is found within feldspar phenocrysts, and feldpsars within a single unit are tightly grouped. Some units show minor contrasts between phenocrysts and matrix. In contrast, associated basalts and lower-T rhyolites in the same area represent different types of magmas that passed through the same crustal column, and have the relatively large internal $^{87}Sr/^{86}Sr$ variability exhibited by common volcanic rocks.

High temperature rhyolitic magmas possess a unique combination of temperature and melt viscosity. Although they are typically 200°C hotter than common rhyolites, the effect on viscosity is offset by lower water contents (~2 wt%), hence their melt viscosities are in the same range as common, water-rich, cool rhyolites ($10^5 - 10^6$ Pa s). However, the high magmatic temperatures dictate that cation diffusion rates are 2 – 3 orders of magnitude greater than in common rhyolites. We hypothesize that this combination of characteristics promotes Sr isotopic homogeneity: viscosities that are too high to permit crystal transfer and magma mixing on timescales shorter than those required for diffusive homogenization of Sr between phenocrysts and matrix (100 – 1000 years). This is untrue for the vast majority of magmas, in which either crystal transfer is rapid (<< 100 years) due to low melt viscosities (basalts and intermediate magmas), or else Sr diffusion rates are so slow that the equilibration time is longer than the lifetime of the system (high-silica minimum melt rhyolites: $10^5 - 10^6$ years).