Dynamical and thermal implications of Martian core formation timescales

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The earliest thermal history of Mars depends mainly on the manner in which it accreted. For instance, a Mars built entirely out of small bodies would have been cold and undifferentiated [1]. Conversely, a collision between two bodies each roughly 10% of a Mars mass (M_m) would have been sufficient to initiate global melting [2]. Melting of silicates is important because it allows rapid percolation of iron and thus core formation. The Hf-W isotope system constrains the timing of core formation [3], though the system can also be affected by garnet crystallization.

Estimates of the Martian core formation timescale span a range of ~1-10 Myr [3, 4], primarily because of uncertainties in the bulk mantle Hf/W ratio [5]. Martian accretion may thus have been either relatively rapid or relatively slow. In either case, Mars' formation likely involved collisions with neighbouring protoplanets of comparable mass ("giant" impacts) as well as impacts with much smaller bodiess. An impactor hitting Mars generates roughly its own mass in impact melt. Regional magma seas generated by such impacts are one possible explanation for the existence of several ancient and distinct reservoirs on Mars [6].

A Mars which accreted rapidly (~1 Myr) would have melted automatically due to the decay of ^{26}Al, irrespective of the size-spectrum of accreting bodies [2]. On the other hand, a more slowly accreting Mars must have undergone at least one giant impact to ensure melting and differentiation. If the Hf/W data suggest a ~10 Myr core formation timescale, they therefore provide information on the kind of impacts Mars suffered. Further constraints on the accretion history of Mars may be derived by considering its current rather slow spin rate. Accretion involving multiple giant impacts tends to result in planets spinning close to the stability limit (period ~ 3 hrs) [7]. For Mars, a late impactor of mass 0.1 M_m has only a ~3% probability of causing Mars to spin as slowly as it is observed to do. There is thus a relatively narrow window of possible impacts which allow melting and core formation to take place, but do not violate spin constraints.

[1] Senshu *et al.* (2002) *JGR* [2] Rubie *et al.* (2007) *Treatise Geophys.* [3] Kleine *et al.* (2002) *Nature* [4] Jacobsen, (2005) *AREPS* [5] Nimmo & Kleine (2007) *Icarus* [6] Halliday *et al.* (2001) *Space Sci Rev.* [7] Agnor *et al.* (1999) *Icarus*.

Biological controls on the late Archaean atmosphere

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The late Archean atmosphere, like the modern atmosphere, was probably a biological construction. Methanogens may be of great antiquity, as may be anammox planctomycetes. Anoxygenic photosynthesisers may have been present 3.5 Ga ago. Oxygenic photosynthesisers probably appeared about 2.9 Ga ago, at the same time as large scale carbonate reefs [2].

Rubisco specificity may have had a crucial role in atmospheric evolution. Rubisco III in archaeal methanogens has a very high affinity for O_2 and operates in settings with very low molecular oxygen. In contrast, the specificity and compensation controls of Rubisco I in cyanobacteria sustain an atmosphere with O_2 in percent and CO_2 in ppm. These competing enzymes and the greenhouse consequences permit a bistable system, either anoxic or aerobic. Such controls may have worked in tandem with inorganic controls such as the impact of UV shielding on the lifetime of atmospheric oxygen [1].

Atmospheric pressure is today maintained principally by the nitrogen burden. In the late Archaean this may have been subject to the balance between anammox emission of N_2, lightning, and the nitrogen cycle mediated by nitrogenase (which must be protected from oxygen). Collectively, the interaction between specificity of biochemical enzymes and the greenhouse may have shaped the late Archaean biosphere. Inorganic geochemistry would have operated within the wider framework set by the biological controls.

[1] Goldblatt, C., Lenton, T.M., & Watson, A.J. (2006) *Nature* **443**, 683-686. [2] Nisbet, E.G., Grassineau, N.V., Howe, C.J., Abell, P.I., Regelous, M., & Nisbet, R.E.R. (2007) *Geobiology* **5,** 311-335.