Forum Comment

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Extensive Noachian fluvial systems in Arabia Terra: Implications for early Martian climate

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The recent article by Davis et al. (2016) and the research Focus Article (Hynek, 2016) in *Geology* focus attention on the problem of Mars' early climate, in particular the necessity of having an early warm, wet interval in order to explain the widespread integrated channel networks indicative of prolonged rainfall over extensive regions of Mars. The presence of these networks on Arabia Terra, as shown by Davis et al., makes it very difficult to support the idea of glaciated highlands (e.g., Arabia Terra) as a long-term source of periodically released water to create valley networks during warm episodes within a generally cold climate regime (as in, e.g., Wordsworth et al., 2015). As both articles point out, this revives the problem of how to achieve climate mitigation in the face of both the faint young sun and Mars' considerable distance from the Sun.

As I have pointed out numerous times (Shaw 2007, 2008, 2014, 2015), there is a straightforward solution to this seeming paradox. Detailed analysis of the likely source of Mars' volatiles, namely some mix of meteoritic material, shows the abundance of reduced carbon and nitrogen compounds, as well as enormous reducing capacity in the form of metal. The processes by which these objects arrive at a planetary surface either result in surface accumulation of still reduced compounds (for relatively small impactors, up to 1 km or so) or the production of a short-lived, highly reduced atmosphere due (mostly) to the reaction of iron with steam either in the atmosphere or at the solid/liquid surface. In the former case, weathering may release some of the volatiles. If the surface material is buried ("subducted," or some version thereof), the reduced compounds and the metal associated with them (and the mainly silicate mix) will first be subjected to hydrothermal conditions, leading to release of reduced gases, or, should burial proceed to magmatic depths, the presence of metal during this initial magmatic degassing will yield a generally reduced gas phase. Thus, these scenarios ultimately result in the (temporary) accumulation of reduced carbon and nitrogen species in the atmosphere followed by photochemical reactions that produce an abundance of reduced carbon/nitrogen/oxygen compounds in the primordial ocean.

In the case of Earth, it is important to understand that this accumulation took place long after the moon-forming impact, during the tail end of the accretional phase. One or two percent of Earth's total mass as an average meteorite mix is enough to produce all of Earth's volatile inventory. In the case of Mars, there was clearly no comparable moon-forming impact, and the energetics of late accretion, due to Mars' lesser gravity, make it easier for surface accumulation of intact (un-degassed) meteoritic material. Degassing of such accumulations on Mars was probably largely a result of interactions between Martian volcanism with this initially meteoritic surface. Volcanic "paving" of Mars and volcano-hydrothermal processing of primordial accreted meteoritic material would have resulted in an early Martian atmosphere, which would also have been (initially) comprised of largely reduced compounds, which would then have been photochemically processed into compounds residing in the early Martian ocean.

In the case of both Earth and Mars the early atmosphere, and especially reduced carbon and nitrogen compounds (principally methane and ammonia), were maintained by continued hydrothermal reprocessing of the organics "stored" in the ocean and in organic-rich sediments. Theoretical calculations, and experimental and field observations (Seewald, 2001; Seewald et al., 1990; Seewald et al., 1994; Seewald et al., 2006; Cruse and Seewald, 2006) strongly support the (abiotic) hydrothermal production of both methane and ammonia from organic (not necessarily biogenic) material. This potential source of regeneration of reduced gases to maintain significant atmospheric levels in the face of photolytic destruction (which is admittedly quite real), has been largely ignored. (For a recent example see Olsen et al., 2016). Such abiotic production of reduced gases was clearly much more important on early Mars (and Earth) prior to the emergence of life, but especially because volcano-hydrothermal activity was certainly greater 4+ billion years ago. The fundamental point is that these very powerful greenhouse gases could well have produced the necessary enhanced greenhouse effect to produce warm conditions on both Mars and Earth. Indeed, the waning of this thermal activity on Mars is a possible explanation of the climate deterioration that took place about 3.5 billion years ago, transitioning from warm, wet conditions to the cold, dry Mars of the present day. A more detailed discussion may be found in Shaw (2008, 2014, 2015).

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