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PLANETARY SCIENCE:

Intermittent warmth on young Mars

Warm and wet conditions could have episodically punctuated a generally cold early Mars climate, according to a multidisciplinary modeling approach that potentially solves a five-decade long debate regards warm early Mars conditions.

Nicolas Mangold

Mars is currently a cold, dry planet but geological observations suggest that this has not always been the case. Erosion by fluvial activity¹, dozens of paleolakes² and widespread surface weathering³ imply that Mars was warm and wet early in its history. While these observations are fundamental pieces of information in the search for past life on Mars, the duration, amplitude and precise conditions of this warm, wet period have puzzled planetary scientists for decades and remain debated. Writing in *Nature Geoscience*, Wordsworth and colleagues⁴ aim to reconcile climatic conditions with geological observations and show that Mars rapidly and repeatedly fluctuated between cold, oxidizing conditions and warmer, more reducing conditions, according to their model that couples the processes that built Mars' atmosphere with those that have modified it.

Geological features such as fluvial landforms¹ (Figure 1) suggest that liquid water flowed on the Martian surface, but climate models have struggled to produce the temperatures needed to sustain liquid water. Recently, it has been shown that a more efficient greenhouse effect can be generated by adding reducing gases such as H₂ into atmospheric simulations, which results in sustained liquid water⁵. Reducing gases would have been released into the atmosphere by volcanic activity, large meteor impacts and crustal alteration, all of which would have been intense on Mars prior to about 3.5 billion years ago.

Wordsworth and colleagues move a step further by investigating the equilibrium between the release of these reducing gases and their destruction by physical and chemical processes. To do this, they propose a model that couples together climatic and geological processes at the surface of Mars, driven by the variable release of reducing greenhouse gases and the oxidation of these gases by processes such as hydrogen escape leading to a negative feedback to the growing greenhouse effect. The number of parameters needed to couple these processes is impressive. It is also a limitation because incomplete knowledge of most of them requires many assumptions to be made. The authors face this problem by taking the mean of 256 stochastic simulations to provide a series of probable solutions. They also exclude parameter values that lead to unrealistic current conditions, or unrealistically long wet periods. The results suggest intermittent warmer, wet and reducing intervals between the overall cold, dry and oxidizing conditions, which mimics terrestrial glacial and interglacial ages controlled by orbital variations. However, while orbital parameters strongly influence Mars' current climate, the intermittency in the proposed scenario is rooted in Mars' inner evolution and impact history, not orbital variations.

Reconciling the model results with geological observations presents some challenges. For example, the large impacts that drove the gas release in the early phases⁶ predate the aqueous features that the model tries to explain by more than 100 million years. Moreover, there is no consensus from observations that the climate was episodically rather than continuously warm during the Noachian, between 4 and 3.6 billion years ago. Conversely, episodes of water activity, limited to intervals of less than 100,000 years, are suggested for the Hesperian, some 3.2 to 3.6 billion years ago⁷, supported by the limited longevity of lakes and their scattered ages^{8,9}. Hence, the intermittency proposed by Wordsworth and colleagues fits well with observations from the Hesperian but less well with those from the preceding Noachian period.

Beyond observations of landforms, when the spectrometer of the Mars Express probe detected clay minerals in 2004¹⁰, rock mineralogy became fundamental to understanding early Mars. Clay minerals are mainly present on rocks that are more than 3.6 billion years in age, while younger rocks record more sulfates. Although more recent studies indicate greater complexity¹¹, this first-order transition from clay minerals to sulfates remains valid. Wordsworth and colleagues' modeling predicts a predominance of wet, reduced phases favorable to clay mineral formation in the earliest periods, in agreement with the observed clay–sulfate transition. However, in their model, such a transition could have occurred several times, depending on the number and intensity of wet intervals. The Curiosity rover will soon explore at Gale crater, a section of sedimentary rocks that recorded a clay–sulfate transition, potentially providing key information on this critical period in Mars' evolution.

Curiosity has also identified manganese-rich minerals inside fractures¹². These minerals require not only water to form, but also strongly oxidizing conditions, potentially opening the case for an oxygen-enriched atmosphere. Far from a Great Oxidation Event that is mainly associated with development of life on Earth, oxidation on Mars is controlled by UV photo-dissociation in the atmosphere and chemical processes in rocks. In their model, Wordsworth and colleagues identify periods of transition towards oxidizing conditions that would be still wet enough to provide a pathway for manganese-rich mineral formation close to the surface, which may explain these in-situ observations in late-stage aqueous episodes.

Wordsworth and colleagues⁴ show that intermittency is the keyword for warmer conditions on early Mars and make predictions that can be tested by future missions, which will in turn help to constrain some of the many parameters in their model. By analyzing Jezero crater, a site that provide evidence of a paleolake and a diversity in rock mineralogy and age, the Perseverance rover may provide some of the missing observations that should help to determine if the young Mars was indeed so hesitant to get warmer.

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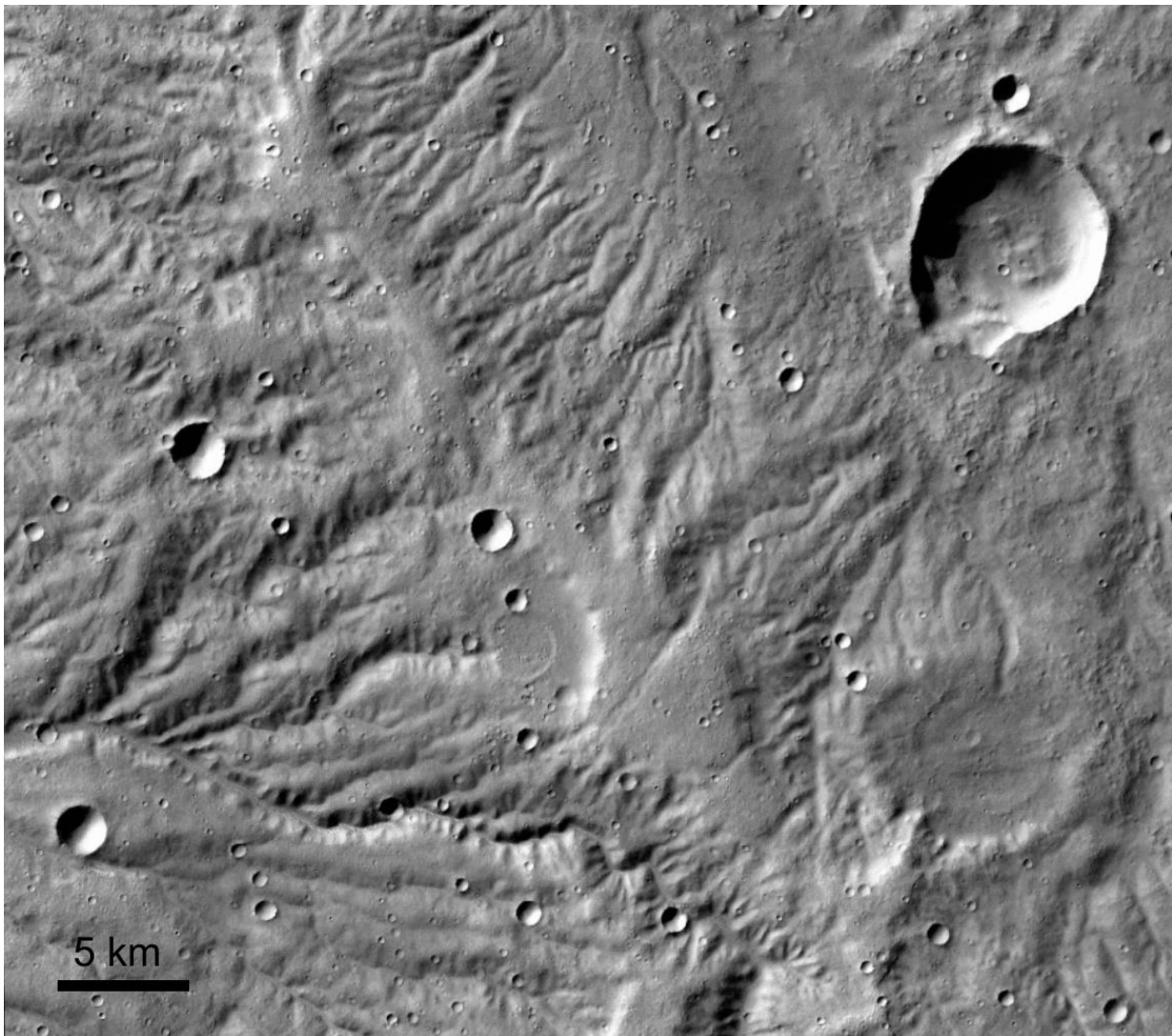


Figure 1: **Fluvial landforms on Mars.** Geologic observations, such as this High Resolution Stereo Colour image of Baskhaus Valles, are evidence of liquid water at the surface of Mars more than 3 billions years ago, which has been hard to reconcile with climate simulations that predict a cold early climate. Wordsworth and colleagues⁴ propose that warm, wet conditions intermittently interrupted the generally cold and dry early Mars because of a balance between greenhouse gas release and their subsequent modification in Mars' atmosphere, providing a pathway to sustain fluvial erosion.

Credit: ESA/MEX/HRSC/DLR/FUBerlin

References:

- (1) Howard, A. D., Moore, J. F. & Irwin III R. P. An intense terminal epoch of widespread fluvial activity on early Mars: 1. Valley network incision and associated deposits, *J. Geophys. Res.* **10**, E12S14, doi:10.1029/2005JE002459 (2005).
- (2) Goudge, T. A., Aureli, K. L., Head, J. W., Fassett, C. I., & Mustard J. F. Classification and analysis of candidate impact crater-hosted closed-basin lakes on Mars, *Icarus* **260**, 346-367, DOI: 10.1016/j.icarus.2015.07.026 (2015).
- (3) Carter, J. Loizeau, D, Mangold, N., Poulet, F., Bibring, J.-P. Widespread surface weathering on early Mars: a case for a warmer and wetter climate, *Icarus* **248**, 373-382 doi:10.1016/j.icarus.2014.11.011 (2015).
- (4) Wordsworth, R., et al. A coupled stochastic model of the climate and redox evolution of Mars, *Nat. Geosci.*, this issue.
- (5) Ramirez, R. M., Kopparapu, R. Zugger, M. E., Robinson, T. D., Freedman, R. & Kasting J. F. Warming early Mars with CO₂ and H₂. *Nat. Geosci.* **7**, 59–63 (2014).
- (6) Large impact basins on Mars formed ca. 4 Gy. Werner, S. C. The early Martian evolution—Constraints from basin formation ages, *Icarus* **195**, 45–60 doi:10.1016/j.icarus.2007.12.008 (2008).
- (7) Kite, E.S., Mayer, D.P., Wilson, S.A., Davis, J.M., Lucas, A.S., & Stucky de Quay, G. Persistence of intense, climate-driven runoff late in Mars history. *Sci. Adv.* **5**, eaav7710 (2019).
- (8) Salese, F., Kleinhans, M., Mangold, N., De Haas, T., Ansan, V., & Dromart, G. Estimated minimum lifetime of the Jezero crater Delta, Mars, *Astrobiology* **20**, 977-993, <https://doi.org/10.1089/ast.2020.2228> (2020).
- (9) Hauber, E., et al. Asynchronous formation of Hesperian and Amazonian-aged deltas on Mars and implications for climate, *J. Geophys. Res.-Planets* **118**, 1–16 doi:10.1002/jgre.20107 (2013).
- (10) Poulet, F., et al. Phyllosilicates on Mars and Implications for the Early Mars History. *Nature*, **438**, 623-628 (2005).
- (11) E.g., Ehlmann, B. E., and C. S. Edwards, Mineralogy of the Martian surface, *Ann. Rev. of Earth and Planet. Sci.*, doi.org/10.1146/annurev-earth-060313-055024 (2014)
- (12) Lanza, N. L. et al. Oxidation of manganese in an ancient aquifer, Kimberley formation, Gale Crater, Mars. *Geophys. Res. Letters* **43**, 7398–7407 (2016).