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Mars: A small and barren planet whose geodynamics are controlled by hydrous mega mantle plumes derived from its mantle transition zone

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Mars is a barren planet, smaller than the Earth's core. Until almost a decade ago, scientists assumed that magmatic and tectonic activity on Mars ceased billions of years ago. However, a growing body of evidence has proved the opposite in recent years. Especially a recent discovery of a regional domal uplift measuring ~4,000 km in diameter around Elysium Planitia, likely to be supported by a currently upwelling giant mantle plume head almost twice the diameter of the Afar superplume on Earth, has puzzled the scientists. That domal uplift should be very young as it is cut by rifts and is partly covered by basic lavas as young as 2 Ma. Another discovery on Mars has revealed a ~400 km thick Mantle Transition Zone (MTZ) between ~1100 km and ~1500 km depth, sitting on the core. The MTZ contains wadsleyite and ringwoodite, which can contain up to 2 wt.% water and other volatiles (e.g., halogens and neon). These volatiles significantly reduce viscosity and make the mantle remarkably fluid. Without a lower mantle, the Martian MTZ should be the sole hemisphere from which mantle plumes can originate.

Trace element behaviors indicate the presence of hydrous minerals (e.g., phlogopite and amphibole) in the mantle source of the Martian meteorites, supporting the volatile-rich interior of Mars. In this study we argue that the existence of phlogopite and amphibole in the mantle can be explained by the phase transformation of wadsleyite in the mantle plumes rising from the MTZ into hydrous olivine by decompression and dehydration at depths shallower than ~1100 km and hydrous olivine into phlogopite and amphibole by the reaction of water and metasomatic fluids at depths shallower than ~300 km. Our petrological melting models suggest that primitive Martian lavas may have been generated by the mixing of magmas with contrasting compositions that originated from (i) a depleted mantle, possibly representing the plumes from the MTZ, and (ii) a highly enriched metasomatized lithosphere, rich in incompatible elements. Based on these findings, we hypothesize that the Martian plumes may be low-viscosity hydrous upwellings from the MTZ driven by the heat of the underlying core.