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Tracing the evolution of a young magmatic plumbing system in Tharsis, Mars using spectrally derived mineralogy

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High-resolution volcanological studies of Martian volcanic systems provide otherwise inaccessible insight into the subsurface magmatic systems that most likely evolved and differentiated over time. These processes can be partially traced on Mars' surface by investigating morphological changes in volcanic features and their spectrally-determined mineralogical composition. However, due to the limited availability of high-resolution images coupled with spectral datasets, our knowledge remains biased toward the largest volcanic systems. The key to constraining the dynamic volcanic evolution lies in small-scale features that record complex eruptive histories. Through a detailed spatiotemporal reconstruction of a dyke-fed plumbing system, we showed that over time, eruptive activity evolved from highly mobile lava flows that erupted along the entire fissure length to more viscous lava flows that erupted at a single location, building up a cone. These constraints suggest a long-lived (at least ≥9 Ma) volcanic system [1] that became chemically differentiated. Remotely-sensed mineralogical analyses of the orbital hyperspectral targeted images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) revealed mineralogical differences across morphologically distinct volcanic units. The smooth-surfaced and widespread lava flows from the central fissure exhibit olivine spectral characteristics, indicating that the magma was sourced from a deep reservoir, likely the mantle or lower crust. In contrast, the finger-shaped lava flows on the summit cone are dominated by high-calcium pyroxene, suggesting a different, more differentiated, magmatic origin. These results indicate magmatic differentiation due to crustal magma storage, possible assimilation, and fractional crystallization upon subsequent cooling within a single dyke-fed system [2]. This study demonstrates that, even without physical samples, valuable constraints on magma source evolution can be obtained from the orbit, improving our understanding of Tharsis's late Amazonian volcanism.

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[1] Pieterek & Jones (2023), *Earth and Planetary Science Letters* 621, 118382.

[2] Pieterek, Payré & Jones (2026), *Geology, doi.org/10.1130/G53969.1.*