Geomorphological constraints on the current eruptive flux in the Tharsis volcanic province

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1. Introduction

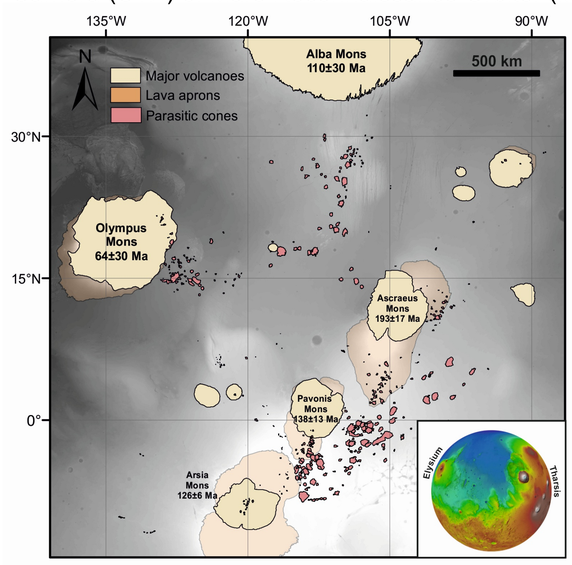
Despite young lava flows (2.4-250 Ma) found on the surface of Mars *(1–10)*, searches for thermal signatures *(11)* and surface changes *(12)* yielded no positive evidence of active volcanism.

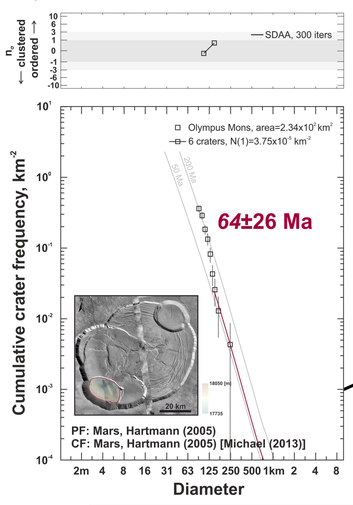
However, several decades of measurements from Mars-based orbiters and Earth-based telescopes without volcanic eruption observed cannot ascertain extinct volcanism.

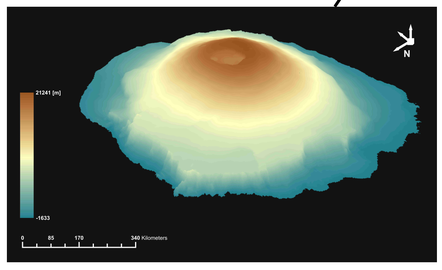
Here, we quantify magma flux in the two largest Martian igneous provinces, **Tharsis** and Elysium, and provide evidence for **active magmatism**.

2. Geological settings & methods

We mainly focus on **Tharsis**, which is the largest volcanic province on Mars. Here, **12 large volcanoes** are accompanied by **574 much smaller, likely parasitic, cones** (>1 km in diameter) mapped by us using datasets from Mars Orbiter Laser Altimeter (MOLA) of Mars Global Surveyor (MGS), Thermal Emission Imaging System (THEMIS) of Mars Odyssey (MO), and Context Camera (CTX) of Mars Reconnaissance Orbiter (MRO).







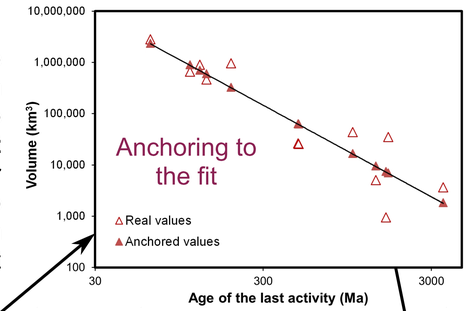
We estimated the volumes and ages of last activity at the summit calderas of the **15 largest Tharsis and Elysium volcanic edifices**:

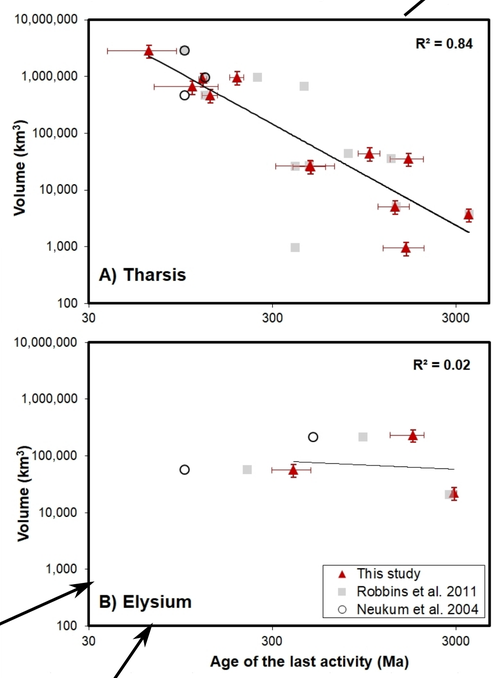
- The calderas were dated by counting craters typically >100 m in diameter with ArcGIS extension CraterTools *(13)* on the **CTX imagery**. Crater statistics and derivation of crater model ages were carried out with Craterstats II *(14)* by applying the **Hartmann's [2005] chronology system** *(15)*.

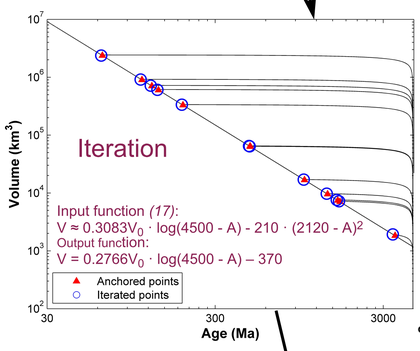
- The volumes were calculated with ArcMap using the **digital elevation model (DEM) from MOLA/MGS (128 pixels/degree)** referenced to the Mars 2000 spheroid in an equirectangular projection.

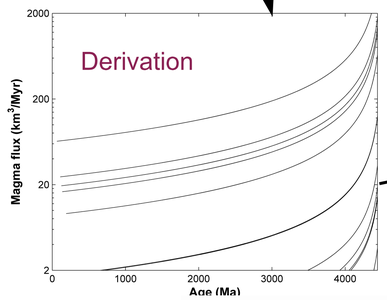
3. Data analysis

Our results for **Tharsis indicate a significant inverse correlation (R^2 = 0.84) between volcano volume and youngest summit caldera age**, consistent with earlier studies *(1, 3, 5)*. Interestingly, we do not see such an inverse correlation (R^2 = 0.02) in the second largest volcanic province on Mars, Elysium.







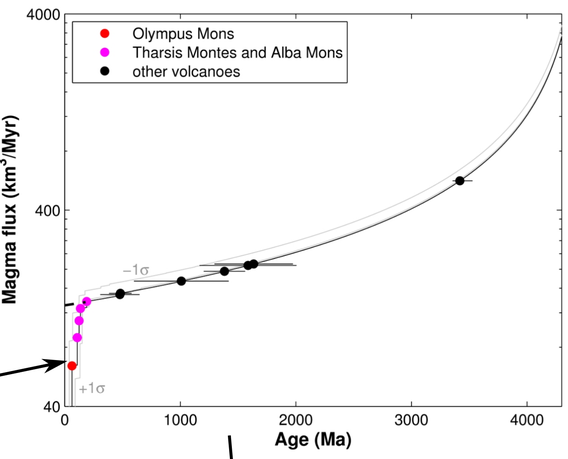


4. Interpretation & discussion

After a coeval beginning of volcanic activity in the entire Tharsis province in Early Noachian *(16)*, the smaller magma reservoirs stopped working early, yielding smaller volcanoes. The **larger magma reservoirs underneath the giant volcanoes** lasted longer and might be **still active**.

Volcano volume (V) is controlled by a function of age (A) and a fraction of initial magma reservoir volume (V_0). Other factors (discussed in our submitted manuscript) include:

- erosion *(18)*
- parasitic cones *(19-23)*
- pyroclastic material *(24)*
- eruption/intrusion ratio *(25)*



5. Conclusions

1) The largest Tharsis volcanoes are probably dormant rather than extinct, with a long-term eruptive magma flux, which may be as high as **~150 km³/Myr**.

2) **Active magma reservoirs** could be expected under **Olympus Mons**, and perhaps the other giant volcanoes.These volcanoes are currently the most probable hot spots through which heat is released from an underlying mantle plume. The heat delivered by such a plume must be supplied by cooling *(26)* and perhaps solidification of the Martian core, as may be soon better understood from the **InSight mission** data.

3) Even though the **ExoMars TGO** has not yet detected gases of volcanic or hydrothermal origin, future detections in the proximity of giant Tharsis volcanoes would not be surprising, as spectral modelling of Thermal Emission Spectrometer (TES) on board of MGS has already suggested *(27)*.

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