IMPACT-INDUCED SUBDUCTION AND SLAB ROLLBACK FOR THE TECTONIC ORIGIN OF THE THARSIS RISE ON MARS. An Yin (Department of Earth and Space Sciences and Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90095-1567, USA; yin@ess.ucla.edu).

Introduction: The Tharsis rise occupying 25% of Mars surface is the largest and youngest tectonic feature on Mars. Its formation has been attributed to (1) activity of a stationary or migrating hotspot, (2) magmatic underplating of the lower crust due to partially molten mantle, (3) protracted volcanic construction initiated by the Late Heavy Bombardment, and (4) impact-induced deep mantle plumes. Delamination of mangle lithosphere was also advocated local uplift of the Tharsis rise.

Since the early mapping by Scott and Tanaka (1986) and more recently the compilation of a newly renovated global geologic map of Mars by Skinner et al. (2006), it has been known that the initial development of individual large volcanic fields was approximately linear trending in the NE-SW direction. The ***age of initiation*** of Tharsis volcanism has become younger from southeast to northwest, starting in the Late Noachian and ending in the Late Amazonian. Associated with the migration of Tharsis volcanic chains is a change in the style of volcanism, from early effusive eruption in the southwest to central-volcano construction in the northwest. Within each volcanic zone, central volcanoes change styles along strike from thin and tall geometry in the southwest (i.e., Tharsis Montes and Olympus Mons) to wide and flat geometry in the northeast (e.g., Alba Patera) across a NE-trending linear boundary. This observation implies an abrupt decrease in lava viscosity across the boundary. Recent work also shows that after the initiation of zonal volcanic fields such as the Tharsis Montes, Late Amazonian small and younger volcanoes were widely developed and are closely related to NE-trending fissures across the Tharsis Montes and Syria Planum.

The Tharsis rise is also dominated by NE-trending grabens that extend >1500 km away from the margins of the rise. Their wide spatial distribution beyond the topographic high region of therise has been a major mechanical obstacle to all the existing Tharsis models advocating vertical loading for its origin, either by a plume from below or by a large load of volcanic construct from above.

Hypothesis: A crucial observation with regard to Tharsis formation is its initial development coinciding spatially and temporally with a volcanic zone along its southeastern margin (i.e., Thaumasia Highland), after which zonal volcanism sequentially swept northwestward across the tectonic province. Examination of the spatial relationship between major impact basins on Mars (Utopia, Hellas, Isidis, and Argyre) and their nearby volcanism suggests that the initial volcanism along the southeast side of the Tharsis rise may have been induced by Argyre impact. This and observations from the Tharsis rise mentioned above leads to a hypothesis that involves three steps of reasoning (Fig. 1): (1) vertical load (ejecta deposits, crustal shortening, and injection of pyroclastic sills) from Argyre impact had produced flexural stresses guiding the impact-induced melts to migrate to the surface; (2) accumulation of volcanic flows and its positive feedback with lithospheric bending caused rupture and later subduction of the Tharsis lithosphere; (3) continuous subduction through slab rollback drove trench retreat and northwestward migration of zonal volcanism; (4) back-arc extension induced scattered volcanism and the development of NE-trending grabens across the Tharsis rise, and (5) delamination of mantle lithosphere dragged down by the sinking slab to the southwest may have led to the development of flat but wide central volcanoes (Alab Patera and Uranius Patera) in the NW Tharsis rise (Fig. 2).

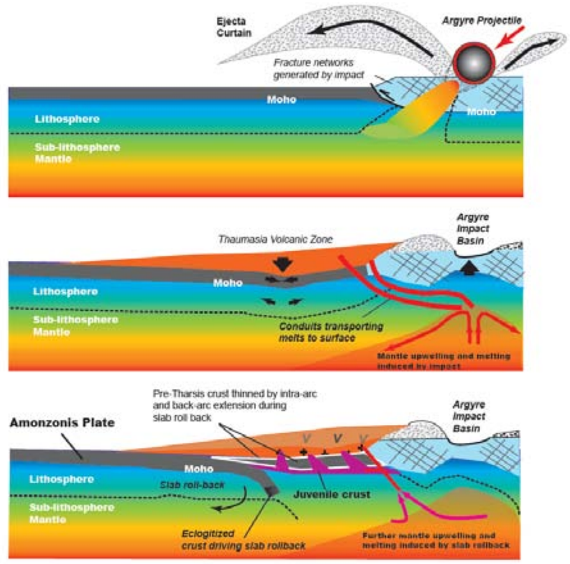

Figure 1. Impact-induced subduction in SE Tharsis.

Model Predictions: The hypothesis makes the following predictions: (A) the Tharsis rise is underlain mostly by juvenile lithosphere created by mantle upwelling in the backarc region, which explains the lack of crustal magnetic anomalies; (B) Tharsis igneous province was mostly generated by arc magmatism that explains (i) the early phase of widespread explosive eruption associated with volcano constructions when fluid content was highest in the mantle and (ii) high-viscosity lava flows matching basaltic andesite or andesite composition, and (C) a foreland basin is present northwest of the Tharsis rise with its dimension requiring its effective elastic thickness to be ~ 300 km; and (D) the Tharsis mantle has been progressively cooled by plate subduction, a prediction consistent with reduction of volcano spacing with time.

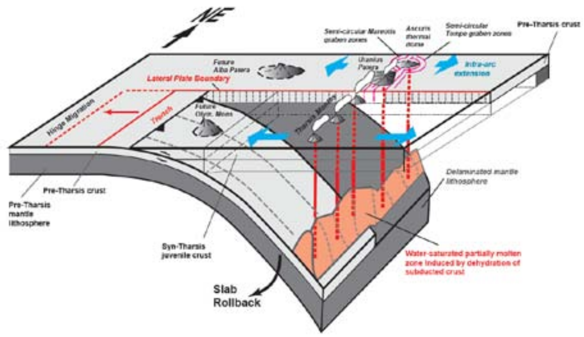

Figure 2. Three-dimensional view of the slab roll-back model. Note that lithospheric delamination is inferred below NE Tharsis.

Model Implications: The proposed tectonic model has three broad implications for the evolution of Mars and Earth: (A) the exceptionally large size of Martian volcanoes in the solar system is likely controlled by (i) a shallow core-mantle boundary that tends to stabilize a subduction system over a long period of time when the tip of the strong down-going plate reached this boundary, and (ii) greater volcano spacing means that mantle melts were transported via much fewer conduits connecting to the surface than those on Earth; (B) initiation of plate tectonics in the solar system may simply be controlled by the initial thickness of the crust as it governs whether the lithosphere was subductable during the narrow time window of heavy bombardment in the early history of the solar system (4.5-4.0 Ga); and (3) Hadean plate subduction could have also been initiated by impact, with subduction producing tonalitic crust first via construction of oceanic island arcs and followed by formation of granitic crust via remelting of the tonalitic crust during crustal thickening induced by arc-arc collision. Subduction was initiated near Syria Planum by early Hesperian volcanic flooding, possibly triggered by the Argyre impact. The positive feedback between volcanic loading and downward flexural warping may have eventually led to lithospheric foundering and subsequent subduction near the dichotomy boundary. In this model, the whole lithosphere was subducted below the Tharsis rise while only the mantle lithosphere was delaminated from the overlying crust and subducted below the Uranius Patera and Alba Patera to the northeast and the Sirenum Terra to the southwest. This model not only explains the widely distributed grabens but also places diverse Tharsis features under a unified tectonic framework: (1) the Olympus Mons aureole zone and the Acheron Fossae uplift as a subduction zone (Fig. 3), (2) the Erebus Montes as a fore-bulge and Amazonius Planitia as a foreland basin, (3) the NW-trending normal faults at Gordii Dorsum and Acheron Fossae as accommodation structures accommodating subduction of a narrow strip of lithosphere, (4) the lack of crustal magnetic anomalies in the Tharsis as a result of juvenile crustal formation, (5) the Thaumasia-Coprates Rise contractional orogen as a retra-arc thrust belt, and (6) the Valles Marineris fault zone as a left-slip transform structure linking NE-trending normal faults in a back-arc setting.

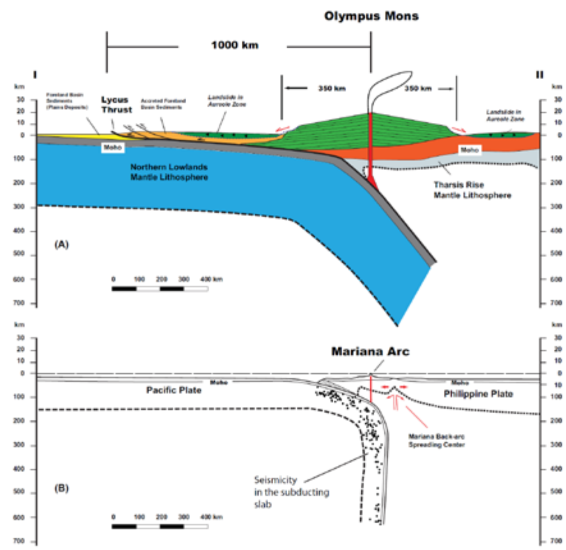

Figure 3. Comparison of inferred subduction below Olympus Mons on Mars and subduction below Marinana arc on Earth.

References: Use the brief numbered style common in many abstracts, e.g., [1], [2], etc. References should then appear in numerical order in the reference list, and should use the following abbreviated style:

[1] Scott, D.H., and K. L. Tanaka (1986) *USGS Misc. Investig. Ser. Map I-1802A*. [2] Skinner Jr., J.A., et al. (2006) *Lunar & Planet. Sci. XXXVII*, 2331.