AN ACTUALLY HOT TECTONIC MODEL FOR THE THARSIS HOTSPOT. D. Mége and P. Masson,
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SUMMARY
Comparison between the Tharsis province on Mars and hotspots on Earth shows that a simple model of aborted
rifting in a crust weakened by a hotspot can account for most tectonic structures observed in this region.

INTRODUCTION
Although Tharsis has been considered as a hotspot for more than two decades, many recent tectonic models of
Tharsis have neglected that Tharsis not only is a volcanically active region, but also was once a volcanically loaded
region. Models based on elastic lithosphere loading ([1, 2]) have never completely satisfactorily accounted for the tectonic structures formed contemporaneously to volcanic activity [2, 3]. Evidence recently reported of probable existence of giant mafic dike swarms [4-6] suggests a new model of Tharsis geodynamic evolution similar to plume tectonics models on Earth. Many details of the model can be found in a full paper [5].

THE MODEL
Early thermal uplift. Similar to hotspots on Earth, plume impingement at the base of the lithosphere close to
the Noachian/Hesperian boundary creates thermal uplift (e.g., [7]), centred on Syria Planum. Compressive
spreading stress at the boundary of the uplifted crust is responsible for compressional deformations circular about
the dome [8], similar to inferred compressive belt around a 2.7-2.6 Gy Yilgarn hotspot [9]. Most ridges from the
Flood basalt eruption and dike swarm emplacement. During early Hesperian, flood basalt eruption occurs
parallel to giant mafic dike swarm emplacement. Analogy is noted with large igneous provinces associated to
terrestrial hotspots, such as the 1.67 Gy Coppermine River basalts and the Mackenzie dike swarm associated to
the Mackenzie hotspot [11], and the 15.5-16.5 My Columbia River basalts, the Monument, Chief Joseph, and
North Nevada rift dike swarms at the Yellowstone hotspot (ref. in [12]). The dike swarms, inferred from
morphostructural arguments [5, 6], allow to infer the principal stress trajectories during emplacement [13].
Analysis of stress trajectories (figure 1, top) shows the existence of a regional tensile stress superimposed on
hotspot-related stresses, which may originate from inflation/deflation events in magma chambers [14] as well as
gravitational loading [15].
Wrinkle ridge formation. Wrinkle ridges [3] begin to form roughly concentric about the centre of the dome on
the lava plateaus while flood lava eruption occurs, in response to thermal subsidence enhanced by isostatic
subsidence (see [16]) induced by loading of the thermally-thinned brittle upper crust. Analogy is found with isostatic
subsidence of the Columbia Plateau and Yakima ridge initiation concentric to the past location of the
Yellowstone hotspot (see [17]). Similar structural characteristics are shared by the Tharsis wrinkle ridges and
the Yakima fold belt [18]. Wrinkle ridge orientation is consistent with orientation of principal stresses resulting
from dike geometry analysis on figure 1 (top), contrary to models considering Tharsis-related stress only [3]. Surface compression during dike swarm emplacement is made possible by transitory local change of principal stress magnitudes resulting from lava plateau subsidence.
Early narrow graben formation. Hesperian narrow grabens (radial and concentric about Syria Planum) formed in
a stress field similar to that existing during dike swarm emplacement; location above dikes may be due to stress
centration at dikes due to their high Young's modulus, and to stress resulting from dike magma pressure [6].
Valles Marineris formation. Valles Marineris is parallel to the early radial grabens (figure 1, top) and
should result from the same stress. Its formation is explained by crust weakening by the hotspot and rifting
along favorably oriented crustal discontinuities, namely the dikes, very similar to models of rifting on Earth (e.g.,
[19]) also accounting for the Poseidon and North Nevada riftings at the Mackennzie and Yellowstone hotspots,
respectively. Absence of plate tectonics allowed very limited extension only [20, 21], slowly proceeding up to
Amazonian [22].
Recurrent magmatic activity. Recurrence of hotspot volcanic activity and dike swarm emplacement has been
frequently observed on Earth (e.g. [23]), and is also featured on Mars at Tharsis after the Syria Planum events
(figure 1, bottom). An Alba Patera-related swarm is identified [7, 24], and magmatic activity at both provinces
are shown to be contemporaneous by analysis of stress field interactions [5].
Hotspot migration. Migration of magmatic activity from Syria Planum to Tharsis suggests relative plume/lithosphere motion. The Tharsis volcanic activity began with emplacement of flood lavas [25], but volcano morphology of the Tharsis Montes suggests that the latest lavas erupted should have been significantly more silicic, and denotes SW-NE migration of the last volcanic activity at the Tharsis Montes, similar to volcanic evolution at the Yellowstone hotspot from the McDermitt caldeira to the Yellowstone caldeira, via the Snake River plain. The 8 km-high permanent Tharsis rift line uplift is interpreted as due to a batholith similar to the thick Snake River batholith [7]. No wrinkle ridges appear to be associated to the Tharsis events, maybe because of lithosphere strengthening by previous magmatic activity.
Conversely, persistency of formation of extensional structures is explained by persistence of a remote extensional stress regime (box in figure 1, bottom).

The model proposed differs from previous tectonic models in the stress sources involved. Previous models have attempted to explain the tectonic structures by loading stress only, whereas the present model suggests that most extension is basically due to a persistent remote stress working in a hot and weakened lithosphere. Volcanic loading stress is however required, in addition to thermal subsidence, for producing the wrinkle ridges. Study of extensional hoop strain variation at various distances from the hotspot would help determine whether more stress is required near the volcanoes than at larger distances, which would denote a requirement for local stress in addition to the remote stress for explaining formation of the radial grabens.