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The Evolution of the Martian elastic lithosphere thickness - A comparison with Earth's continents

M. Grott (1), D. Breuer (1)

(1) Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany

Planetary lithospheres exhibit nonzero mechanical strength over geological timescales which is generally expressed in terms of the elastic lithosphere thickness T_e. On Earth, T_e estimates for oceanic lithosphere follow the depth to the $600°$C isotherm, reflecting the growth of lithospheric strength as the lithosphere cools. However, the interpretation of elastic thickness values on the continents is not as straightforward and the thermal state is only one factor controlling T_e. In particular, the state of the crust-mantle interface (mechanical coupling or decoupling of crust and mantle), the thicknesses and proportions of the mechanically competent layers as well as the intraplate stresses play an important role. A transition from the state of mechanical decoupling to coupling is caused by lithospheric cooling and results in a bimodal distribution of the observed elastic thickness values.

Estimates of the Martian elastic lithosphere thickness imply that T_e evolved from values below 20 km in the Noachian to more than 100 km in the Amazonian period. Furthermore, T_e rapidly increased from ∼30 km to ∼70 km during the Hesperian, a behaviour reminiscent of the bimodal T_e distribution on Earth's continents. We have investigated the evolution of the Martian elastic lithosphere using one-dimensional thermal evolution models and the strength envelope formalism. We show that the rapid increase of lithospheric strength in the Hesperian may be caused by a change of the mechanical behaviour of the lithosphere at that time, i.e., a transition from a decoupled to a coupled crust-mantle lithosphere caused by planetary cooling. The results strongly depend on the crustal and mantle rheology and a dry Martian crust can be ruled out. Also, we find that the observations are best compatible with a wet mantle rheology.