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Giant impacts, heterogeneous mantle heating and a past hemispheric dynamo on Mars

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The martian surface exhibits a strong dichotomy in elevation, crustal thickness and magnetization between the southern and northern hemispheres. A giant impact has been proposed as an explanation for the formation of the Northern Lowlands on Mars. Such an impact probably led to strong and deep mantle heating which may have had implications on the magnetic evolution of the planet. We model the effects of such an impact on the martian magnetic field by imposing an impact induced thermal heterogeneity, and the subsequent heat flux heterogeneity, on the martian core-mantle boundary (CMB). The CMB heat flux lateral variations as well as the reduction in the mean CMB heat flux are determined by the size and geographic location of the impactor. A polar impactor leads to a north-south hemispheric magnetic dichotomy that is stronger than an east-west dichotomy created by an equatorial impactor. The amplitude of the hemispheric magnetic dichotomy is mostly controlled by the horizontal Rayleigh number Ra_h which represents the vigor of the convection driven by the lateral variations of the CMB heat flux. We show that, for a given Ra_h, an impact induced CMB heat flux heterogeneity is more efficient than a synthetic degree-1 CMB heat flux heterogeneity in generating strong hemispheric magnetic dichotomies. Large Ra_h values are needed to get a dichotomy as strong as the observed one, favoring a reversing paleo-dynamo for Mars. Our results imply that an impactor radius of ~ 1000 km could have recorded the magnetic dichotomy observed in the martian crustal field only if very rapid post-impact magma cooling took place.