THE MAGNETIC CRUST OF MARS. Jafar Arkani-Hamed (Earth and Planetary Sciences, McGill Univeristy, Canada, jafar@eps.mcgill.ca)

Introduction: The magnetization of the Martian crust is of remanent origin that was mainly acquired when the core dynamo was active. Although it is not possible to determine detailed vertical variations of the magnetization of the Martian crust on the basis of magnetic data analysis alone, it is possible to estimate the thickness of the magnetic part of the Martian crust using other independent observations. The magnetic layer is bounded at the bottom by the depth to Curie isotherm of its major magnetic minerals, and at the top by the depth to the base of a near surface zone that has been demagnetized by impact-induced shock waves. This paper studies the effects of these two factors on the potentially magnetic layer of Mars. I also demonstrate that the secondary magnetization acquired by the lower crust in the absence of the core dynamo has little contribution to the observed magnetic anomalies.

Depth to the Bottom of the Magnetic Layer: The depth to Curie isotherm depends on the thermal state of the Martian crust. A total of 24 models are investigated for the thermal evolution of Mars using parameterized convection models similar to those of Stevenson et al [1], but have time dependent stagnant layer on the convecting mantle. Effects of 8 major physical parameters on the thermal evolution of Mars, and thus on the depth to the bottom of the potentially magnetic layer, are estimated. The parameters considered are 1) the initial temperature of Mars immediately after chemical differentiation of possible magma ocean, 2) the total radioactive content of the planet, 3) partitioning of the radioactive elements in to the crust, 4) Potassium content of the core, 5) possible supper heated core, 6) the depth dependence of the thermal expansion coefficient, 7) initial thickness of the crust, and 8) the elastic to ductile transition temperature of the stagnant lid. The viscosity is temperature and pressure dependent in all of the models, and the thermal boundary layers are determined using global Rayleigh number. Figure 1 shows the depths to the bottom of the potentially magnetic layers of the models for the three major magnetic carriers. The open symbols are the thickness at 4 Gyr ago. The filled symbols denote the potentially magnetic layers, established in the absence of the core dynamo and when the layers attained their minimum thickness. Except for 2 models, Models 7 and 17, the potentially magnetic layers of the models are comparable, suggesting a magnetic layer of about 50km if magnetite, or ilmenite-hematite lamellae, is the major magnetic carrier.

Impact Demagnetization of the Uppermost Crust: The absence of the magnetic anomalies over the giant basins of Mars suggests that the crust beneath the basins is demagnetized by the impact events [2,3,4]. However, no systematic investigation has been carried out on the impact-induced demagnetization of the uppermost crust of Mars on a global basis. In this section the shock pressure distribution produced by small and intermediate size impacts is calculated inside the crust to estimate the average depth of the demagnetized zone in Cimmeria and Sirenum Terrae, adopting the method used by Mohit and Arkani-Hamed [4] for intermediate size craters. Figure 2 shows the demagnetized zones due to impacts that produce different size craters. The shock pressure inside each curve is higher than 2 GPa, assumed to be the threshold pressure for complete demagnetization. Note that the curves are not concentric. The center of each curve is defined by the depth of penetration of the projectile, taken as the radius of the projectile [5]. The old Cimmeria and Sirenum regions are almost saturated by impact craters with diameters less than 100km, and there are numerous visible and buried craters of diameters 50-200 km [6,7]. The figure suggests that the uppermost 10-20 km of the crust was demagnetized by impact shock waves in the early history of the planet. This is supported by the fact that the freshly looking craters with less than 500 km diameter that could have demagnetized the upper 10-20 km to distances within a diameter of about 250 km show no effects of demagnetization [4].

Secondary magnetization of the lower crust: The thermal remanent magnetization (TRM) of the potentially magnetic layer of Mars is acquired mainly during the active period of core dynamo and partly after the dynamo ceased to exist. Thermal evolution models show that the upper part of the crust in all of the models cooled below the Curie temperature of its magnetic minerals and acquired TRM in the presence of the core field (the primary magnetization). The lower parts of the crust were hot in the early history of Mars but later cooled below the Curie temperature of the magnetic minerals, and acquired TRM in the absence of the core field, but in the presence of the magnetic field produced by the upper parts of the crust (the secondary magnetization). The secondary magnetization is calculated by extending Arkani-Hamed's [8] technique to include a demagnetized uppermost crust with several different thickness. It is concluded that the bulk magnetization (vertically integrated magnetization) of the upper crust is the major source for the magnetic field that magnetized the lower crust. Thicker demagnetized zone, requires stronger magnetization of the thinner potentially magnetic layer beneath, and vice versa.

Moreover, the primary magnetization of the upper crust is the main magnetic source of Mars, as was concluded by Arkani-Hamed [8].

References: [1] Stevenson, D. J., et al. (1983), Icarus, 54, 466-489. [2] Acuna, M. H. et al. (1999), Science, 284, 790-793. [3] Hood, L. et al. (2003), GRL, 30, 10, 1029/2002GL016657. [4] Mohit, P.S., and J. Arkani-Hamed (2004) Icarus, 168, 305-317. [6] Frey, H.V. (2003) *LPS XXXIV*, Abstract #1838. [7] Frey, H.V. et al., (2003) *LPS XXXIV*, Abstract #1848. [8]ArkaniHamed,J.(2003)*JGR*,*108*, E10, 5114,10.1029 /2003JE002049.

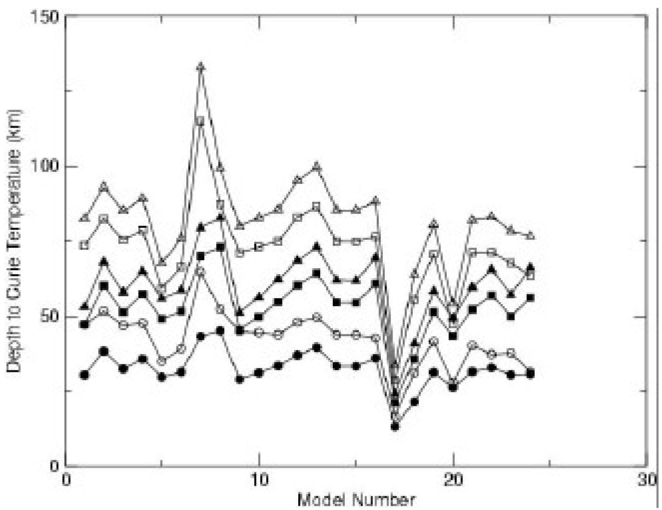

Figure 1. Depth to Curie temperature of hematite (trangules), magnetite (squares) and pyrrhotite (cricles). The open symbols are the thickness at 4 Gyr ago. The filled symbols denote the potentially magnetic layers, established in the absence of the core dynamo and when the layers attained their minimum thickness.

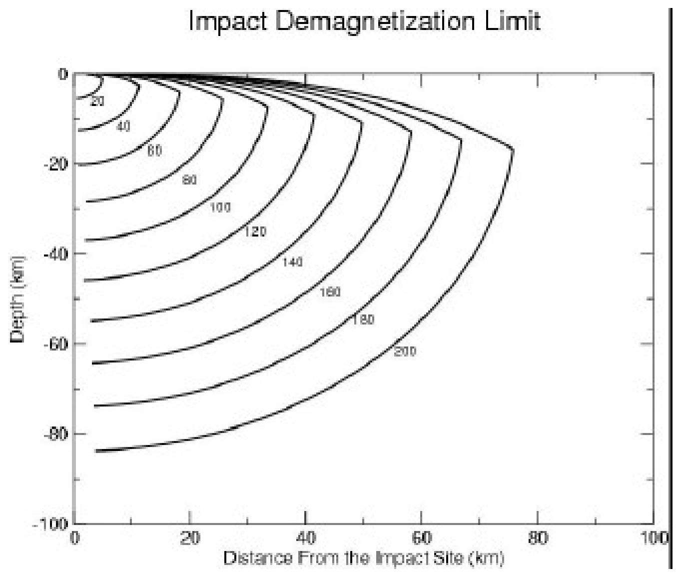

Figure 2. Isobaric curve showing the shock wave pressure produced by impacts. The curves denote 2GPa pressure. The numbers on the curves are the diameter of the resulting crater in km.