LOW-MAGNETIC EARLY NOACHIAN CRUST OF MARS. D. Boutin[1] and J. Arkani-Hamed [1,2], [1](Earth and Planetary Sciences, McGill University, Montreal, QC, H3A-2A7, Canada, dboutin003@sympatico.ca), J. Arkani-Hamed [1,2] [2](Department of Physics, University of Toronto, Toronto, ON M5S 1A7, Canada).

Introduction: No distinct magnetic signatures observed by Mars Global Surveyor (MGS) over the impact craters and impact-related Quasi-Circular-Depressions (QCD) with diameters greater than 200 km located on South Province, south of 30S and ranging from the west of Hellas basin to the east of Argyre basin, implying a weakly magnetized Noachian crust of the Province [1]. As part of the highly cratered Southern hemisphere of Mars, the South Province crust was formed early in the history of the planet, and it would have taken ~100 Myr to cool below the magnetic blocking temperature of its magnetic minerals, during which the minerals could have acquired appreciable thermoremanent magnetization if a strong core dynamo existed. The weakly magnetized South Province implies no strong core dynamo during this period [1]. It is quite likely that the magma ocean in the upper mantle of Mars in the early history of the planet was a global phenomenon and the crust was forming on a global scale, because during the growth of Mars embryo planetesimals accreted from all directions. The lack of appreciable magnetization of South Province suggests the possibility that the primordial crust of Mars elsewhere is also formed in the absence of a strong core dynamo and is weakly magnetized. If so, the observed strong magnetic anomalies of Mars are likely due to the magnetic source bodies formed at later times when a strong core dynamo existed. This seems to be an interesting possibility, which we are presently investigating. Here we extend our previous study area to cover the entire surface of Mars, and study the magnetic signature of all available QCDs and craters greater than 250 km in diameter on Mars, a total of 265 QCDS and 28 craters [2].

Magnetic Signature of QCDs: We closely follow the procedures previously adopted [1]. Figure 1A shows the magnetic anomaly map of Mars derived at about 400 km latitude using the high-altitude MGS nighttime radial component magnetic data acquired from 1999 to 2006. No further data manipulations are made. The map presents essentially raw data, except for averaging over each bin of 15 x 15 km horizontal and about 10 km vertical which is the total altitude variations of the spacecraft over a given crater or QCD.

The crustal structure beneath craters and QCDs with diameters larger than 250 km is determined using MOLA topography [3] and the recent JPL gravity model of Mars [4]. Briefly, the global gravity and topography data of Mars are analyzed in the spherical harmonic domain and the global crustal thickness variations are determined. All of the craters show appreciable mantle uplift beneath. This distinct signature is used to identify the impact-related QCDs, 239 out of the total of 265 QCDs are likely impact-related. Figure 1B shows the global distribution of the impact-related and non-impact-related QCDs in red and black colors, respectively. Figure 1C shows the global distribution of the craters.

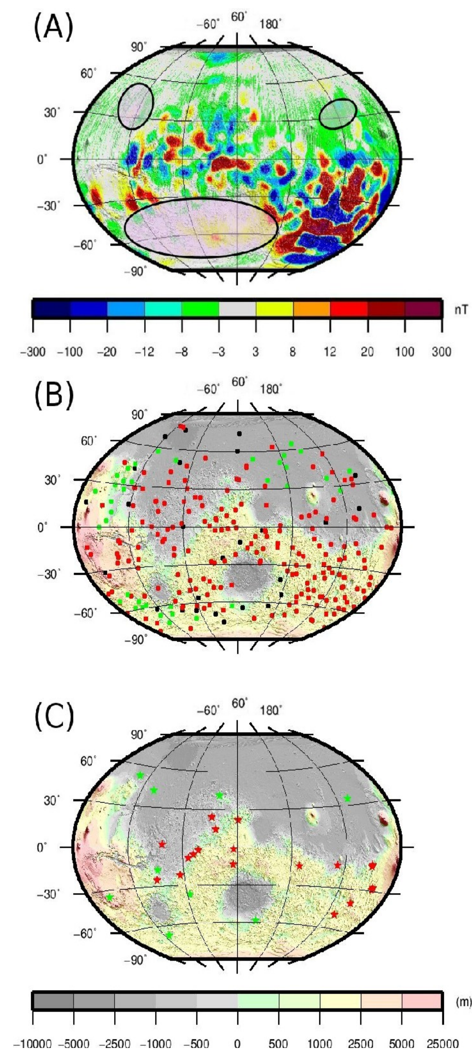

Figure 1

The impacts that have created the craters and impact-related QCDS are capable of demagnetizing the entire 60 km crust beneath and creating distinct magnetic anomalies at the satellite altitude of 400 km in case the crust was appreciably magnetized prior to the impacts [1]. We derive the magnetic anomalies of each of these features on a 15x15 km equal area grid using the radial component of the high-altitude night-time MGS data. This provides a means to identify the QCDs and craters with magnetic signatures lower than 3 nT at 400 km, as seen in green in Figures 1B and 1C, called hereafter as the super low-magnetic craters and QCDs. We find that 38 out of the 239 impact related QCDs and 9 out of 28 craters are super low-magnetic.

The majority of craters and impact-related QCDs on northern lowland and Tharsis bulge have almost no magnetic signatures. This is consistent with the observation that the crust in the lowland is demagnetized by the mechanisms proposed to have created the lowland. It is also shown that a major part of the crust in the Tharsis bulge was created in the absence of a strong core dynamo [5,6]. Majority of the craters and impact-related QCDs on the highlands have appreciable magnetic anomalies. The impacts have partially demagnetized the strong magnetic source bodies underlying the highlands, especially in Terra Cimmeria and Terra Sirenum, resulting in strong magnetic signatures.

Low Magnetization of Early Noachian Crust: Besides the Noachian crust of the Southern Province, there are two relatively smaller areas depicted in Figure 1A (the two circles in the northern hemisphere) which have high concentrations of the super low-magnetic QCDs (Figure 1B). Also some super low-magnetic craters are located in these areas (Figure 1C). The Noachian age of these three areas with appreciable distances apart supports the suggestion that no strong core dynamo existed in the early history of the planet.

We modeled the magnetization of the crust surrounding each of these super low-magnetic QCDs and craters, adopting the modeling technique of Boutin and Arkani-Hamed [7] and assuming that the related impact has demagnetized an otherwise uniformly magnetic layer of 60 km thickness. The Noachian crust surrounding the super low-magnetic QCDs and craters is very low magnetic, about 30 times lower than the magnetization of the crust beneath Terra Cimmeria and Terra Sirenum [8].

Two other magnetic data are used to verify the super-low magnetic areas: the low altitude MGS data acquired at altitudes lower than 200 km during the aerobraking phase of the satellite, and the magnetic intensity calculated at 185 km altitude on the basis of the Electron Reflectometer data [9]. Accordingly, two magnetic intensity maps are constructed for each super low-magnetic craters and QCDs. Both data sets are found quite sparsely distributed, and are not useful for reliable modeling purposes. However, both maps support our observation based on the high altitude MGS data.

References: [1] Arkani-Hamed J. and Boutin D. (2012) Icarus, 209–230. [2] Frey H. (2011) personal communication. [3] Smith D. et al. (2003) MGS-M-MOLA-5-MEGDR-L3-V1.0. [4] Konopliv A.S. et al. (2011) 410–428. [5] Arkani-Hamed J. (2004) JGR, 109, E03006. [6] Johnson C.L., Phillips,R.J. (2004) EPSL, 230, 241–254. [7] Boutin D. and Arkani-Hamed J. (2006) Icarus 181, 13–25. [8] Connerney J.E.P. et al. (1999) Science 84, 794–798. [9] Lillis R.J., et al. (2004) GRL, 31, L15702.