MODELING OF MARS' LARGE-SCALE CRUSTAL MAGNETIZATION. C. Milbury[1] and G. Schubert[1,2], [1]UCLA, Department of Earth and Space Sciences, 595 Charles Young Drive East, Los Angeles, CA 90095-1567 (cmilbury@ucla.edu), [2]Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90095-1567.

Introduction: It is certain that a dynamo operated in Mars' history, although many of its properties remain undetermined. As the crust cooled through the Curie temperature it would have become magnetized in the direction of the dynamo magnetic field. As Mars evolved, processes such as chemical alteration, magmatism, impact cratering and crustal thinning, altered the crustal magnetization structure and the resulting magnetic field. The original magnetic signature can be expected to have been preserved only on global scales.

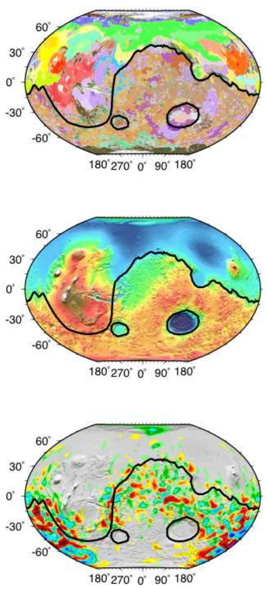

Figure 1. Global plots of geology (top) [1], MOLA topography (center) and radial magnetic field (bottom) [2]. For the geologic plot, the brown colors are for the Noachian (oldest); purple, blue, and green colors are for the Hesperian (middle), and the red, orange, and yellow and white colors are for the Amazonian (youngest) epochs. The black line indicates the dichotomy boundary and the Hellas and Argyre impact basins. The portions of crust that are north of the boundary and inside the basins are excluded from the magnetization models.

Methods: We present a very simple model of the crustal magnetization in order to match the large-scale features of the magnetic field observations. The model is based on a spherical shell magnetized by an internal dipolar magnetic field that has since been removed, similar to what may have occurred on Mars. Equations from Runcorn [3] are used to calculate the components of the magnetization for an array of paleopole positions that span the globe. The paleopole grid is spaced by 15º in latitude and by 30º in longitude for a total of 134 paleopole positions. Crust is removed from areas where processes have occurred that most likely altered the magnetization structure, including the northern lowlands, the Tharsis volcanic province, and the Hellas, Argyre, and Isidis impact basins (see Figure 1). The magnetic field due to the remaining distributions of magnetization are computed using the forward magnetic field code of [2] for each crustal magnetization distribution and compared with the available published models of the magnetic field data [2,4-8]. Spherical harmonic coefficients of the radial component of the magnetic field for the models presented here are computed for degree and order 2-9. Spherical harmonic coefficients of the above referenced six published models of the radial magnetic field are computed. The correlations of the spherical harmonic coefficients of the radial magnetic field models and the models of the observed radial magnetic field are calculated. The paleopole that maximizes the correlation coefficient is determined for each of the above six models of the data. Differences in correlation for a given model of the data are assessed by the q parameter of Cohen [9], which compares two values of the correlation and determines how different they are. It is given by the following equation:

$q = \frac{1}{2}\ln\left[\frac{1+r_1}{1-r_1}\right] - \frac{1}{2}\ln\left[\frac{1+r_2}{1-r_2}\right]$, where r_1 and r_2 are correlation coefficients that are to be compared. A value of $q<0.1$ relates to coefficients that have a small difference in correlation. In the above equation r_1 is set to the maximum value of the correlation coefficient and r_2 is the value of the correlation coefficient for a given model that gives a value of $q<0.1$. Medium and large differences are given by $q>0.3$ and 0.5, respectively.

	degree/order l=2			degree/order l=3		
Published model of data	**pole lon/lat (ºE/ºN)**	**r_1(= max corr**	**r_2(q<0.1)**	**pole lon/lat (ºE/ºN)**	**r_1(=max corr**	**r_2(q<0.1)**
Purucker et al. (2000)	75/-15	0.2603	0.165	180/0	0.3698	0.28
Arkani-Hamed (2002)	105/-15	0.4545	0.375	135/-15	0.5272	0.455
Cain et. al (2003)	135/15	0.6604	0.603	135/-15	0.5768	0.505
Arkani-Hamed (2004)	105/45	0.3778	0.293	135/15	0.3784	0.294
Langlais et al. (2004)	180/0	0.4829	0.406	135/15	0.4931	0.417
Whaler & Purucker (2005)	165/45	0.7695	0.725	180/30	0.3889	0.297

Table 1. Maximum value of the correlation coefficient, corresponding paleopole position, and value of r_2 for $q<0.1$ for degree/order 2 and 3.

Results and Conclusions: Expansions of the radial component of the magnetic field were carried out to degree/order 2 through 9, but only degree/order 2 and 3 showed significant correlation between the models of this paper and the models of the observations. Table 1 shows the maximum values of the correlation coefficients, the paleopole that corresponds to the maximum correlation, and the value of r_2 that gives a value of $q<0.1$ for each of the six published magnetic field models we compare with our models. The correlation coefficient for degree and order 4-9 are ~0.1, with the exception of the correlation of the Langlais et al. [2] model, which has a maximum correlation of 0.396 for l=3. The highest correlation coefficients correspond to the model of [8], and the lowest correlation coefficients correspond to the model of Purucker et al. [4]. Figure 2 shows the paleopole positions for models that have a correlation >0.6 and values of q<0.1. The models of [6,8] satisfy both of those conditions for degree/order l=2.

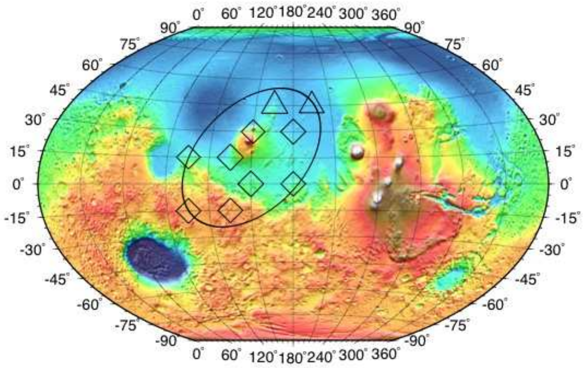

Figure 2. Paleopoles that have a correlation >0.6, and a small difference in correlation (q<0.1). The model of [8] is designated by triangles and the model of [6] is designated by diamonds.

At the largest scale, l=2, our crustal magnetization models for certain paleopole positions produce radial magnetic fields in good agreement with observations (Figure 3). It is expected that the signature of the ancient Martian dynamo still preserved in the crust of Mars should be observable best at the global scale since the processes that modify crustal magnetization generally operate at smaller scales.

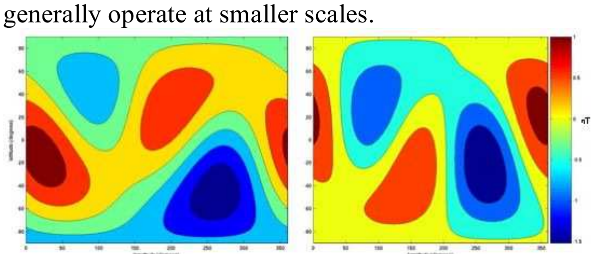

Figure 3. Radial magnetic field model of [8] (left) and our model (right) for the paleopole at 165ºE/45ºN. These models maximize the correlation for l=2.

All the models with good correlation give paleopole postitions that are located within the same region and are in general agreement with previously determined paleopole positions. The overlap of our models and the poles given by [10-12] is focused in the region centered near lon/lat=180ºE/30ºN. There is a cluster of poles that is more widely spread to the west of 180ºE/30ºN, which was used as an argument for polar wander. The poles we determine are in agreement with published poles and are at low latitudes, which is evidence of polar wander. There is another cluster of poles near the south pole, which may be associated with features that formed near the end of the dynamo regime when the magnetic pole was closely aligned with the current rotational axis, as suggested by [13].

In summary, we determine paleopole positions by modeling Mars' crustal magnetization as due to a magnetized spherical shell, and removing magnetization from regions that have clearly been affected by processes that occurred post-formation. By making these simple assumptions we find paleopole positions that reproduce the large-scale features of the observed magnetic field and are in agreement with published paleopole positions [10-12].

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