GEOMETRIC ANALYSIS OF LINEATION PATTERNS IN THE MARTIAN MAGNETIC FIELD.

D. Kobayashi[1] and K. F. Sprenke[1], [1]Department of Geological Sciences, University of Idaho, Moscow, ID 83844-3022. daisuke@vandals.uidaho.edu; ksprenke@uidaho.edu.

Introduction: Hypotheses of the origin of the magnetic anomalies on Mars have included seafloor spreading, hydrothermal alteration, accretion of terranes, magmatic intrusions, and mega-impact. However, the hypothesis of our study is that the magnetic anomalies on Mars represent hotspot tracks on ancient Mars. As evidence, an analysis of lineation patterns derived from the ΔBr magnetic map is presented. This map, representing the mean change of the radial component of the field with latitude, is an excellent proxy for the Bθ component at Mars Global Surveyor mapping altitude. Through a geometric analysis of the ΔBr map, we have found that the lineations in the Martian magnetic field form small circles about two distinct poles, a result consistent with our hypothesis of a hotspot track origin.

Data: The ΔBr map shows Martian crustal magnetic anomalies (**Fig.1**) [1]. This map is thought to be largely free of the effects of the external magnetic field, allowing detail of the magnetic anomalies.

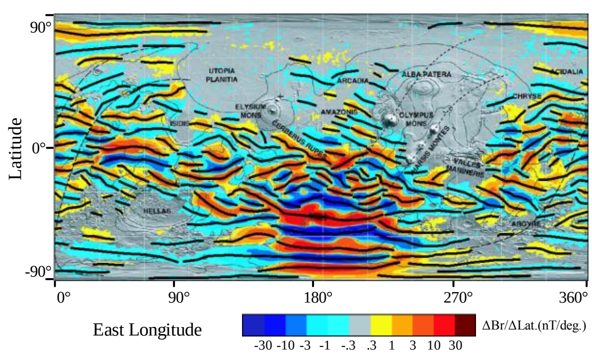

Fig. 1: ΔBr map shows the crustal magnetism on Mars with higher details than the preceding models [1]. The black lines are digitized lineations following the strike of each elongated magnetic anomaly.

The data were collected at an altitude of about 400 km. At this altitude, the anomalies are merged together and the maxima and minima of magnetic anomalies are not generally coincident with the location of the crustal sources. However, in this study, the pattern of the original global magnetic anomalies, which is certainly apparent, is the parameter of interest.

Hypothesis: Intense magnetic anomalies on Mars due to crustal sources have raised many possible explanations. We claim that the linear magnetic anomalies on Mars represent ancient hotspot tracks.

Hotspot tracks on Earth, such as the Hawaiian Island chain, occur as a result of the lateral lithospheric movement over a fixed plume of magma rising from the core-mantle boundary. On Earth, hotspots, although fixed in the mantle, generally appear to move eastward as the lithosphere moves generally westward over them. In plate tectonics theory, this phenomenon is referred to as the “westward drift.”

The cause of the westward drift on Earth is hotly debated. Many researchers believe that it is caused by convection cells in the mantle. On the other hand, Alfred Wegener in 1915 and many researchers since have explained the westward drift in terms of rotational drag due to the tidal effect of the Moon on the lithospheric plates. Recent research suggests that Mars may have had large satellites in its early history when its core dynamo was active [2-3]. The purpose of this study is to analyze the pattern of magnetic anomalies on Mars for evidence of lithospheric drift.

Method: The lineations shown in **Fig. 1** follow the strike of the magnetic anomalies by following the trends of the "ridges" and "valleys" in the magnetic data. The lineations consist of multiple lines connecting equally-spaced digitized points. In order to find the best-fit plane for all the lineations, the lineations are translated to the origin of the Cartesian coordinate system by normalizing each to its centroid. The best-fit plane through a set of points always passes through the centroid. With the least-square method, the equation for the best-fit plane for all the lineations together is obtained. Those lineations consistent with the best-fit plane form a dominant set of lineations. With the same operation described above, the best-fit plane for each lineation is calculated. Then the RMS residual of each lineation is calculated to see how deviated each is from the best-fit plane. Lineations with low RMS (more consistent with the best-fit plane) are sorted out to form the first set. Those of a bad fit form a new subset, which is further analyzed for other possible poles with the operation described above. For the set that is sorted out, the best-fit plane is calculated in order to obtain the equation for the pole of the plane.

Results: The linear magnetic anomalies on Mars can be divided into two groups (**Fig. 2-a and 2-b**) and remainders (**Fig. 3**). The two groups form separate sets of small circles about poles offset from the present-day spin axis. One pole is near 272W 80N, the other near 111W 67N. Furthermore, the equators of these poles nearly pass through eight of the 20 major giant impact basins on the surface of Mars (**Fig. 4**).

Interpretation: The fact that the magnetic anomalies follow small circles strongly suggests that the pattern of the anomalies is associated with the rotation of the planet about these poles at some time in the past. If the lithosphere on Mars was decoupled from the asthenosphere, fixed hotspots in the deep mantle would have traced out hotspot tracks oriented along small circles.

If the lithospheric drift was caused by tidal drag associated with an ancient moon orbiting on the prevailing equatorial plane, then large fragments of that ancient moon, if any survived, would have fallen on the equator of the planet. The equator of Set 1 comes very close to fitting five basins. The other equator nearly goes through three other basins. Arkani-Hamed [2-3] notes that the probability that random impact craters will trace within a few degrees of any great circle on Mars are small (less than about 0.1 for three impacts; less than 0.01 for five impacts). The fact that eight of the 20 giant impacts on Mars happen to fall near the two independently determined equators would be an extremely unlikely coincidence.

Discussion: One prediction of the hypothesis that the magnetic lineations on Mars are the result of east-west lithospheric drift over hot spots is that the paleomagnetic poles at the time of magnetization should agree with the purported rotational poles at the time of magma emplacement. They do not. The mean location of the north paleomagnetic pole on ancient Mars is near 230E 25N, well south of the poles of this study. However, the magnetized crustal sources on Mars are different from those on earth. The relatively thin intrusive igneous bodies on Earth require tens of millions of years to cool and acquire magnetization. On the other hand, the magnetized sources on Mars are generally thought to be several tens of kilometers thick and would take about 100 million years to cool. Thus, if the magma was intruded while poles of this study were at the spin axes, the intrusions may not have cooled and acquired magnetization until as long as 100 million years later when the pole had perhaps wandered to the paleomagnetic pole. Interestingly, the paleomagnetic pole is consistent with another possible equatorial great circle that passes through the giant Acidalia, Chryse, and Sirenum basins[3].

Reference: [1] Connerney, J.E.P. et al. (2005) *Proc. Natl. Acad. Sci, 102,* 14970-14975. [2] Arkani-Hamed, J. (2005) *Geophys. Res. Letter, 28,* 3409-3412. [3] Arkani-Hamed, J. (2009) *Icarus 201,* 31-43.

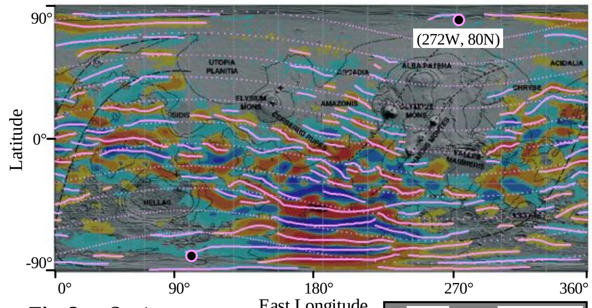

Fig. 2-a: Set 1

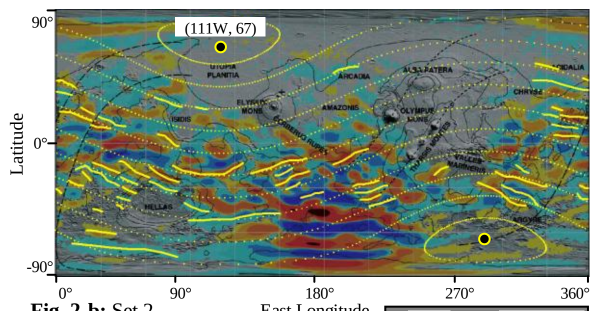

Fig. 2-b: Set 2

Fig. 2: (a) The lineations of Set 1 follow the small circles about a pole at 272W, 80N. **(b)** The lineations of Set 2 follow the small circles about a pole at 111W 67N.

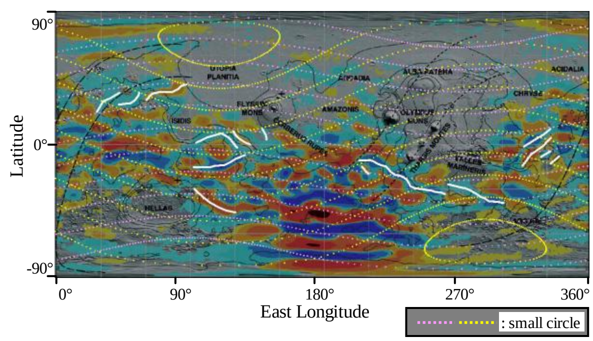

Fig. 3: The lineations of remainders do not fit the small circles of Sets 1 and 2.

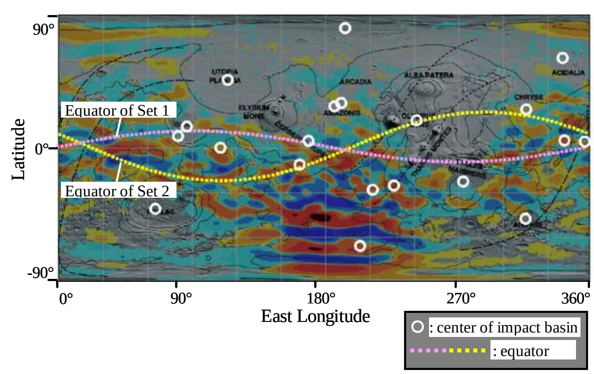

Fig. 4: The equator of Set 1 passes through five of the 20 giant impact basins. The equator of Set 2 passes through three impact basins.