ANALYTIC SIGNAL IN THE INTERPRETATION OF MARS SOUTHERN HIGHLANDS MAGNETIC FIELD. D. Ravat[1] and J. Miller[1,2], [1]Southern Illinois University Carbondale (Dept. of Geology 4324, SIUC, Carbondale, IL 62901-4324, USA; E-mail: ravat@geo.siu.edu), [2]Presently at: WesternGeco (1625 Broadway. Suite 1300, Denver, CO 80202, USA)

Introduction: Linearity and high-low-high-low pattern of some of the large amplitude magnetic anomalies in the southern highlands of Mars was initially interpreted as the result of ancient seafloor spreading [1]. We investigated possibilities of the magnetic field reflecting Earth-like tectonics by reconstructing magnetic field at 150 km altitude over North America and North Atlantic Ocean from near-surface and satellite-altitude data [2] and found that narrow Earth-scale tectonic features (such as continental rifts, sutures, and seafloor spreading patterns) would be difficult to interpret correctly from magnetic data at 100-200 km and higher altitude. Magnetic pattern at 150 km elevation over Mars southern highlands has similar characteristics as the pattern on Earth. However, on Earth, at these altitudes, what one observes is the coalescence of strong local magnetic anomalies into ovals and patterns associated with very large geologic provinces (1000s of km length and width), large oceanic quiet zones, and regional-scale large heat flow variations. Many linear appearing magnetic features on Earth, at 150 km elevation, result from false tectonic continuity and are artifacts of anomaly coalescence; such a possibility for the linear magnetic features on Mars cannot be discounted. In terms of interpreting tectonics, we are limited by the 100-200 km altitude data (the highest resolution data we currently have). With these data, we can still model bulk characteristics of magnetic sources (average magnetization, width, thickness, etc.) and attempt to understand them. In this paper, we model bulk magnetizations associated with the prominent linear magnetic anomalies and one positive-negative anomaly pair in the southern highlands of Mars using Z-component variation (negative of Br-component) as well as its analytic signal field. The analytic signal field has certain desirable characteristics in terms of interpretation of sources and its modeling leads to important constraints on positioning of magnetic sources.

Modeling of Z-component and Analytic Signal Fields: With the exception of demagnetization associated with some of the impacts [3], there is no surface expression [4, 5, 6] associated with much of the magnetic pattern of Mars. Therefore, we infer that the source regions of magnetization have been buried by impact debris and, where appropriate, other geologic formations. In Terra Sirenum/Terra Cimmeria regions of the southern highlands, the magnetic pattern suggests complex interfingering of sources (Figure 1a), making it difficult to infer rigorously the nature of the source regions. To aid the interpretation, we use the analytic signal method where the length of the gradient vector of the anomalous field (amplitude of analytic signal or AAS) is computed (Figure 1b). The AAS field has desirable properties that can be used to infer edges of 2-d and 3-d wide sources [7, 8, 9] and approximate locations of 2-d narrow and 3-d compact sources [10].

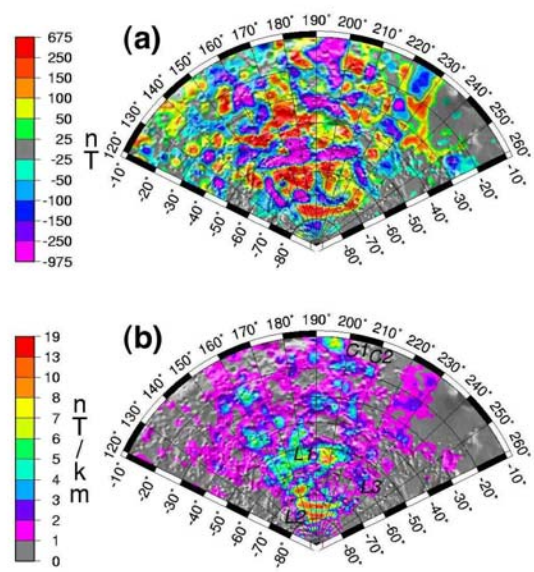

Figure 1. (a) Z-component magnetic field of the southern highlands of Mars; (b) the AAS field of the region. At this scale, the AAS relative maxima show the approximate locations of major magnetic sources. Features L1, L2, L3. C1, and C2 are modeled in this study. For L2, the relative maxima show the approximate northern and southern boundaries of the bulk source.

Refinement in positioning of the lateral boundaries can be made by modeling the anomaly and its AAS field. The AAS field is especially useful for this purpose. Being a derivative quantity, the AAS field has a greater sensitivity to depths of sources than does the Z-component anomaly field. Generally, the magnitude of the modeled AAS field can be controlled by changing significantly the depth to the bottom of sources without affecting the anomaly field. Whereas the depth to the top affects both the anomaly and AAS fields significantly. Also, from the observation height of 100-200 km, the product of magnetization and thickness of a source cannot be considered constant; thus, when the thickness is doubled, the magnetization is not exactly halved and vice versa. (The constancy of the product approximately holds for models derived and tested with 400 km altitude data for Earth and Mars.) Unfortunately, the AAS field is also susceptible to enhancement of noise and, therefore, during the interpretation process, an optimum balance between fitting the anomaly and the AAS field must be achieved.

Linear features. Using modeling of Z-component as well as analytic signal variations, we show that the southern highlands magnetic data can be explained by only two east-west, semi-parallel, long, linear, strong, and most probably oppositely magnetized features (L1 and L2 in Figure 1b). Even though opposite polarities of the long, linear sources are feasible (Table 1), the inferred source regions are separated by too large a distance (> 1000 km) to be ascribed to the process of seafloor spreading even if they are considered buried under the impact debris.

Table 1 gives the bulk characteristics of the modeled features. The magnetization (assuming constant thickness) is highly variable along L1 and L2, but models can be justified consisting of either localized intensification with respect to linear source regions or coalescence of fields into linear patterns from unrelated geologic sources. If the former is the case, then both L1 and L2 appear to be candidates for a tectonic scenario consisting of 'multitude of dikes' in a crustal rift setting. The best fitting magnetic inclinations for L1 and L2 have 20° and 50° spread, respectively. Thus, it is possible that each of these features may have been caused during a single magnetic polarity event. The area of Liu Hsin crater (53.6°S, 188.4°E) has been modeled as a demagnetized zone within L1.

Semi-circular features. We also investigate the origin of dipolar appearing adjacent positive-negative Z-component anomaly pairs (e.g., the region of C1 and C2 in Figure 1b). It was discovered during the study that the nature of the analytic signal field allows one to reduce a part of the potential-field ambiguity regarding the nature of such sources. Particularly, the following question can be answered: Is the Z-component anomaly pair caused by a single near-horizontally magnetized source or two adjacent obliquely to near-vertically and oppositely magnetized source regions? We use the terms 'single' or 'two' above in the sense of 'bulk source region(s) containing many smaller sources'. Using model studies, we demonstrate that for a near-horizontally magnetized single source producing a positive-negative dipolar Z-component anomaly pattern, the analytic signal field shows only one maximum overlying the source region. On the other hand, for obliquely to near-vertically and oppositely magnetized two adjacent sources leading to the similar dipolar pattern, the analytic signal field exhibits two adjacent maxima overlying the source regions (such as C1 and C2 in Figure 1b). This recognition is important because most other forward and inverse modeling methods are not able to resolve the above ambiguity. Even though such models may appear to match the anomalous magnetic field with either of the above two alternative source configurations, they will not be able to match the analytic signal field with both the alternatives.

Table 1. Characteristics of derived magnetic sources. Depths to sources are with respect to MOLA derived planetary radii for the respective locations.

AAS Feature (Figure 1b)	Length/ Width or Diameter (km)	Magn. (A/m)	Depth to top and bottom (km)	Inc. /Dec. (deg)
L1	L2000/ W210-240	12.5 to 27.5	10-50	-70° to -90°/ 0°
Liu Hsin region	D135	27.5	10-50	80°/ 180°
L2	L1100/ W60-270	15 to 55	~0-40	50° to 100°/ 0°
L3	L500/ W150	17.5	10-50	-90°/ –
C1	L300/ W180	25	30-70	80°/ 180°
C2	D300	40	30-50	-80°/ 0°

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