Paleopole reconstruction of Martian magnetic field anomalies. P. Thomas[1] (paul.thomas@dlr.de), M. Grott[1], A. Morschhauser[2], F. Vervelidou[2], [1]Department of Planetary Physics, German Aerospace Center (DLR), [2]GFZ, German Research Center for Geosciences.

Introduction: Investigating a planet's magnetic paleopole position can reveal important information on events like polar reversals or true polar wander (TPW). A variety of investigations have been performed [1,2,3,4,5] usually reporting the best fitting, or a cluster of paleopole positions. These investigations indicate that analyzing the same anomaly using different assumptions can lead to different conclusions for the paleopole positions associated with the underlying sources [5]. To address this issue we applied the method developed by [6] which has the benefit that no assumptions concerning the geometry of the magnetic source are necessary. In addition, this method provides a measure of misfit for the calculated paleopole position and a confidence limit can be defined to determine an area of admissible paleopole locations.

Five crustal magnetic field anomalies will be discussed here. One is the Australe Montes anomaly which has been investigated by [4], four of them are isolated anomalies identified by [7]. They will be denoted as follows: The four anomalies from the publication of [7] will be denoted A1, A2, A3, and A4. They are located at 52°S / 2.5°W, 64°S / 28°E, 57°N / 167°E, and 49.5°N / 169°E, respectively. The Australe Montes anomaly is located at 81°S / 23.4°E and will be denoted A. Montes.

Method: To apply the method of [6], isolated crustal magnetic field anomalies are chosen. Here an isolated anomaly is defined by the absence of a surrounding magnetic field from sources outside the anomaly itself. Further, it is assumed that the anomaly's magnetization has been acquired during a geologically short period within a constant main magnetic field, leading to an anomaly with uniform magnetic orientation [6]. To calculate a paleopole position, a number of *N* equally spaced dipoles with uniform orientation are distributed within the radius R_0 (Fig. 1 / red circle) [6] on the Martian surface. In the same way a distribution of *N* observation points inside the radius R_1 (Fig.1 / black circle), with $R_0 < R_1$, is generated and the downward component of the magnetic field is determined from a magnetic field model at 120 km altitude. Here we use the spherical harmonic model up to degree and order 110 by [7] calculated from the entire Mars Global Surveyor (MGS) data set. Because the magnetic orientation is set a priori, the remaining unknowns are the *N* magnetization strengths M_i of the *N* dipoles. Since it is assumed that $M_i \geq 0$, M_i is calculated using a non negative least square fit algorithm [8], taking only B_z into account. From M_i, a forward model of the magnetic model field can be calculated and the residuals and standard deviation between the model and the spherical harmonic magnetic field can be determined (Fig. 1). The repetition of this calculation for all possible magnetic orientations in steps of 1° in inclination and 2° in declination leads to a distribution of standard deviations for the different magnetic orientations. The paleopole position of every forward model can then be calculated from the magnetization orientation unit vectors using standard coordinate transformations [9] that take the location of the anomaly into account. Here we adopt the convention that the paleopole location is defined as the south magnetic pole [9].

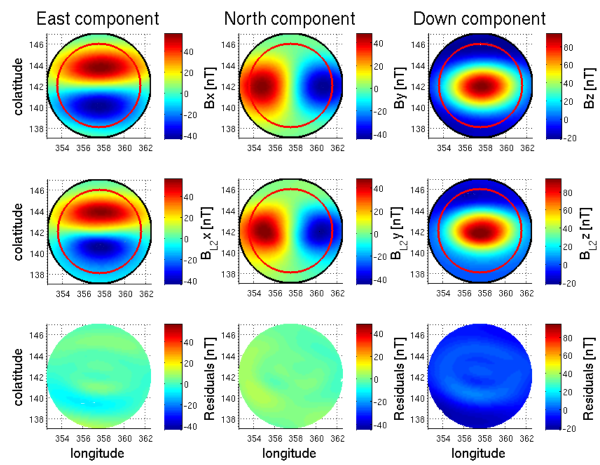

Fig 1: *A1 anomaly with the three components of the spherical harmonic magnetic field (top), in comparison to the best fit magnetic field model (middle) and the corresponding residuals (bottom). The root mean square of the residuals is 6.9 nT for the downward component of the magnetic field, indicating a close fit of the model to the data. The dipole distribution radius (red circle) and the observation point distribution radius (black circle) are shown for reference.*

Usually only the best fitting paleopole location is reported using the model that has the minimum standard deviation, i.e., the smallest residuals in comparison to the spherical harmonic magnetic field (Fig. 1). Here an area representing the region of admissible paleopole locations will be derived based on the assumption that the anomaly's magnetic field may be disturbed by surrounding fields. The root mean square (rms) of the stray fields in the annulus between R_1 and R_0 is then taken as an upper bound for the standard deviation of admissible orientations.

Results: Sensitivity tests indicate that admissible paleopole locations stay unaltered if changes in the inversion parameters like dipole or observation point distribution are made. Therefore, all calculations have been performed with the same configuration in terms of R_0, R_1 and altitude h. Here we use $R_0 = 4°$, $R_1 = 5°$, and $h = 120$ km. It is worth noting that variations of R_0 and R_1 can change the strength of the surrounding fields, and thus change the extent of the region representing admissible paleopole locations.

As an example, Fig. 1 shows the residuals for A1 between the three components of the modeled magnetic field, and the components of the spherical harmonic magnetic field. The rms of the residuals is 6.9 nT representing an excellent fit. Residuals obtained for A2 and A4 are similar, whereas the results for A3 and A. Montes show deficiencies in the fit, which are caused by one ill fitting magnetic field component.

Fig. 2 displays the confidence limits of the five anomalies bounding the regions of admissible paleopole locations by contour lines. Confidence limits for the A2 and A. Montes anomalies enclose almost the entire northern hemisphere, with no limitation in longitudinal extent. This implies that a calculated paleopole could be located anywhere within the northern hemisphere, which is caused by relatively large field contributions between R_0 and R_1 resulting in large thresholds for the rms confidence limit.

Sensitivity of results with respect to the choice of R_0 and R_1 has been tested for the A. Montes anomaly. Depending on the extent of the annulus, surrounding fields have a rms field strength between 11 and 19 nT, as compared to the 14 nT contour line shown in Fig. 2 (orange line). This variation has a small effect on the size of the bounding region for A. Montes, but it remains to be investigated for the other anomalies.

In comparison, admissible paleopole locations for A1 and A4 are much better constrained, enclosing regions in the vicinity of the Isidis basin and near the geographic South Pole, respectively. Therefore, similar to [3], we conclude, that at least once in the Martian history a polar reversal took place changing the magnetic pole from one hemisphere to the other. Furthermore, the results obtained for A4 indicate confidence limits close to the Isidis basin (Fig. 2), supporting a TPW event [3] for Mars.

Conclusions: We have applied the method of [6] to calculate regions of admissible paleopole locations from magnetic field data. Various tests with synthetic as well as real data substantiate that the best fitting paleopole position can change when inversion parameters like observation height or anomaly size are varied. However, regions of admissible paleopole locations remain nearly unaltered. This confirms the robustness of the method for interpreting results obtained from modeling orbital data, instead of considering the best fitting paleopole locations only.

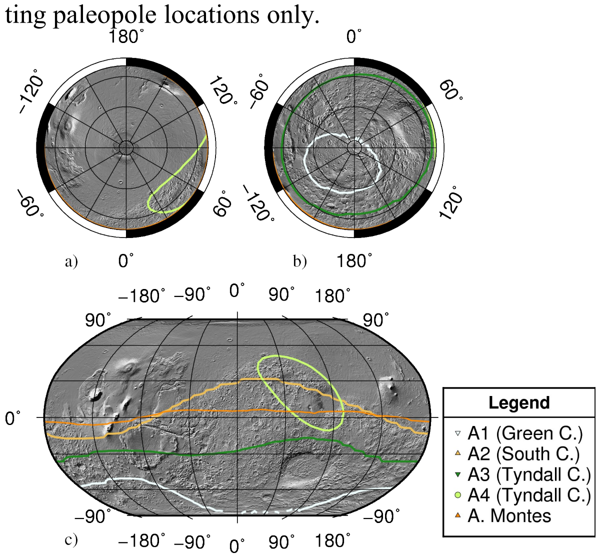

Fig. 2: *Results of the five paleopole reconstructions. Colored lines enclose the confidence regions for the different anomalies. A1 and A3 correspond to admissible paleopole locations in the southern hemisphere (legend: inverted triangle). A2 and A. Montes correspond to paleopoles in the northern hemisphere (legend: triangle). Paleopoles associated with A4 are located close to the Isidis basin and indicate a TPW event. a), b): stereographic projections. c): Robinson projection. Contours are plotted on a MOLA shaded relief map.*

The results presented here support a scenario of polar reversal for the Martian dynamo field with admissible paleopole locations near the rotational poles. The confidence limit obtained for A4 close to the Isidis basin supports the occurrence of a TPW event. Preliminary investigations of other isolated anomalies indicate confidence limits in similar regions and support these conclusions. Also, investigations using varied inversion parameters might lead to better constrained paleopole locations for A2 and A3 if the influence of stray fields surrounding the anomalies can be reduced by optimizing R_1 and R_0.

References:

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