Geophysical Research Abstracts, Vol. 7, 04499, 2005
SRef-ID: 1607-7962/gra/EGU05-A-04499

A correlation between remnant magnetic fields and high-energy radiation incident on Mars

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Mars has had a dipolar magnetic field but the dynamo mechanism that produced it was probably extinguished about 3500 My ago [1]. The only traces of this field are now the strong remnant magnetic anomalies (up to $>$650 nT at 200 km altitude) that were detected (2000) by the magnetometer MAG-ER (Magnetometer and Electron Reflectometer) on board the Mars Global Surveyor mission [2]. The main geomagnetic field, of internal origin, shields the surface of the Earth from the bombardment of the Solar Event Particles (SEP) and Galactic Cosmic Rays (GCR) - the two main sources of the space radiation - which is essential for the maintenance of life as we know it on our planet. Ever since that are records of the geomagnetic field, a magnitude decrease of the total field has been verified and presently accentuated. At the present decrase rate, the geomagnetic field will possibly invert its polarity some 2000 years from now and it is known from palaeomagnetic studies that there is a period where the field is almost, if not completely, annulled, between reversed polarities [3]. It is possible that, in some regions of the terrestrial surface, remnant magnetic fields are strong enough (ex. mineralized zones in magnetite or pirrhotite) to form micron local magnetospheres with protective effect from the GCR and SEP. On Mars the strongest magnetic anomalies of remnant origin are observed in the oldest terrains of Noachian and Hesperian age, Terra Sirenum/Terra Cimmeria, between the latitudes 40žS and 70žS and longitudes 180žW and 210žW. This region reveals complex tectonic features, so far interpreted as relating to the Tharsis upwelling [4]. Not unlike those on Earth, the mapped anomalies show axial symmetry that may indicate Noachian rifting processes. As [6] showed, crustal magnetism, like most other geomorphologic features, shows a dichotomized distribution. The 2001 Mars Odyssey mission carries a detector (MARIE - Martian Radiation Environment Experiment) that measured radiations between 15 and 500

MeV per nucleon, which are the most harmful because of its ionizing effect in living tissues. Concerning GCR, the lower the solar activity is, the higher their energy. On the other hand, SEP are directly correlated with solar activity. MARIE data are crucial if any projects are to be made for the human exploration of Mars. Landing on a naturally sheltered area may mean that radiation shielding requirements are less stringent, hence reducing mission weight and cost. The present work intended to map the total energy which was detected by all of MARIE sensors (except the Cerenkov detector, uncalibrated) during the early 2001 Mars Odyssey mapping phase, between March 16 and March 23, 2002 [5], which was a calm solar period. Due to uncertainty arising in the data time tag - leading to uncertainty in location - only those data that had less than 0.01% difference between uncorrected and corrected time tags were used. The detected energies were then averaged over 100x100 Km bins on the planetary surface and the logarithms of the averages were mapped. This map is not especially enlightening, showing a large number of peaks that are due to individual SEP events. To smooth the data and render it more manageable, we have adjusted a cubic trend surface to the averaged logarithms. The present work also addresses the correlation of data from those two instruments MAG-ER and MARIE in order to infer the protection degree that magnetic anomaly zones confer against the solar wind and the cosmic rays, as stated in [7], in a situation of dynamo-generated magnetic field absence. Confirming [7], the crustal fields appear to locally shield the surface of Mars from GCR and SEP, at least 400 Km into space. Local radiation maxima (Utopia) and minima (Terra Sirenum) are geographically close, respectively, to local magnetic anomalies minima and maxima. The fact that the strongest magnetic anomalies are found in the Terra Sirenum region indicates that, if anything, on radiation safety reasons, this might be one of the more suitable landing sites for the first human explorers of Mars.

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