Interpretation of a magnetic map of the Valles Marineris region, Mars. M.E. Purucker[1], B. Langlais and M. Mandea[2], [1]Geodynamics Branch, GSFC and Raytheon ITSS, Greenbelt, MD 20771, USA (purucker@geomag.gsfc.nasa.gov), [2]IPG-Paris, France (langlais@ipgp.jussieu.fr, mandea@ipgp.jussieu.fr).

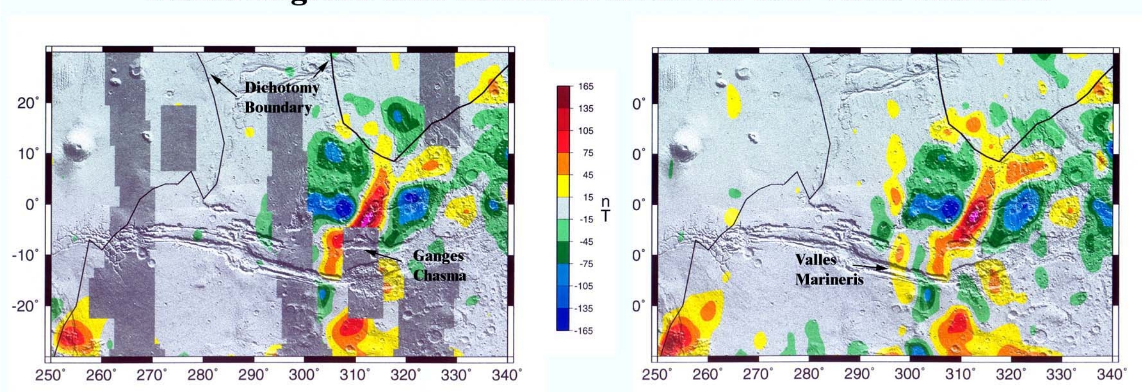
Summary: A new magnetic map of the Valles Marineris region is interpreted in terms of left-lateral faulting. This is the first evidence for substantial strike-slip faulting here. We also see evidence for larger offsets, perhaps as much as 300 km in magnitude and in the opposite sense, farther to the north at Ganges Chasma. Truncation of major magnetic features is also evident, and may reflect removal of magnetic rock from Valles Marineris. The most striking magnetic feature in the region is a long (1200 km), intensely magnetic (1-6 A/m in a 20 km layer) anomaly that is truncated and/or offset at the eastern terminus of Valles Marineris. This anomaly lies underneath Shalbatana Vallis, a major outflow channel, for much of its extent. The anomaly bifurcates and ends near the crustal dichotomy boundary. Based on the truncation of the anomaly at the north wall of the eastern terminus of Valles Marineris, we suggest that the strata exposed here may represent a surface exposure of the highly magnetic material. In contrast, the highly magnetic material evident in maps of the Terra Cimmeria region seems to be deeply buried.

Introduction: On Earth, magnetic field observations are used for structural geologic reconstructions [1] and resource exploration [2]; we expect they may have similar utility on Mars, especially given the strength of the Martian magnetic field of crustal origin first discovered by Mars Global Surveyor (MGS) [3].

Making the map: The data used in making the latest maps of the Valles Marineris region were taken from both the aerobraking (80-200 km altitude) and mapping (400 km altitude) phases of the MGS mission. The aerobraking data, made available by Acuna [4], were averaged over equiangular 3-dimensional blocks of 1 degree by 1 degree by 10 km in latitude, longitude, and altitude, respectively. The altitude is defined with respect to a sphere of radius 3393.5 km. The magnetic field data (Br, Btheta, and Bphi) are given in a spherical coordinate system with Br defined positive outward. Standard deviations are calculated for all bins with 3 or more measurements. Bins with less than 3 observations are not included in the solution reported here. The aerobraking data were collected at all local times but are dominated by dayside observations. A map made using this low altitude data, continued to an altitude of 200 km and shown with dark gray bands in areas of inadequate data coverage, is shown in Figure 1 (left,[5]).

The mapping orbit data through Aug. 24, 1999 over the entire region was used to fill in areas of incomplete data coverage. Because of the greater influence of external magnetic fields at the higher altitude of the mapping orbit, only nighttime Br data has been used. As in our previous work [5], we reduced these magnetic field observations to a common altitude via an intermediate step in which we fit n irregularly distributed magnetic field observations to an icosahedral mesh of m dipoles. Our dipole basis consists of an equal-area mesh with average spacing of 77 km (1.3 degrees). The new map, shown in Figure 1 (right), assimilates the aerobraking (3797 observations) and mapping (6992 observations) data into a map of the radial magnetic field at 200 km

Radial magnetic field calculated at 200 km over Valles Marineris



From Aerobraking (80-200 km alt) — From Aerobraking and Mapping Orbit (400 km)

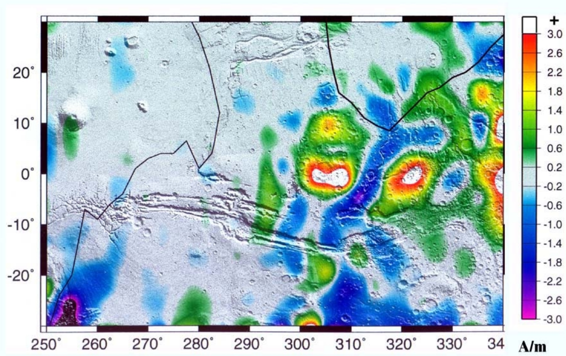
Figure 1

altitude. The correlation between the 10789 Br observations and the Br calculated from the magnetization solution at observation locations is 0.971. The resolution of Figure 1 (right) varies as a function of the amount of low-altitude data. That resolution is lowest in areas without low-altitude data (dark gray bands on Figure 1 (left)).

Interpretation and Discussion:

The measured magnetic signal represents the product of a magnetization times a layer thickness. The layer thickness on Earth is the depth at which the relevant magnetic material loses its permanent magnetization, typically 40 km under the continents. We have assumed here a comparable thermal and petromagnetic regime but we emphasize that a variety of opinions exist [6], [7]. Under this assumption, the range of magnetizations in the Valles Marineris region is –3 to +4 A/m (Figure 2).

Magnetization Model



Vertical magnetizations
40 km thick crust

Figure 2

The magnetization map shown in Figure 2 is made on the assumption that the true magnetizations are radial. Assuming a radial magnetization, as done here, tends to minimize the required magnetization. Inasmuch as these magnetizations are larger than typically encountered in many terrestrial rocks [8], we feel such an assumption is justified. However, it should be possible, if certain assumptions are made about the nature of the magnetic sources, to solve for the true magnetization directions within some of the bodies. As can be seen from a comparison of Figures 1 (the magnetic field map) and Figure 2 (the inferred magnetizations), an assumed vertical magnetization causes the fields to be centered over their sources and the steepest field gradients correspond to the boundaries between regions of differing magnetizations.

Although the Valles Marineris are widely regarded to be tectonic grabens whose location may be controlled by the stress regime associated with the Tharsis rise [9], there has been little evidence for substantial strike-slip faulting associated with, or subsequent to, graben formation. The apparent offset of 3 magnetic features, all by approximately 150 km, as they intersect Valles Marineris from the north (Figure 1, right), suggests left-lateral faulting of a comparable magnitude at the canyon boundary if the magnetization vector is assumed to be vertical. A similar argument can be made farther to the north, at Ganges Chasma, where a 300 km offset in the opposite sense is evident. We will be investigating alternative tectonic scenarios as further evidence becomes available on the direction of magnetization here and as further geologic and geophysical constraints can be provided. One of the most interesting possibilities, based on the truncation of the magnetic anomaly in the north wall of the eastern terminus of Valles Marineris, is that the strata exposed here may represent a surface exposure of the highly magnetic Martian crust. As such, it may provide a critical key to understanding the origin of the early Martian crust and the primordial Martian dynamo.

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Additional Information: These maps, and associated programs, data sets, and reprints are available in digital form at the authors' web site, http://denali.gsfc.nasa.gov/research/purucker/mars_mag.html