RIDGED PLAINS UNITS ON THE MARGINS OF MARTIAN IMPACT BASINS R. Wichman and P.H. Schultz, Dept. of Geological Sciences, Brown University, Providence, RI, 02912

Although the elevated ridged plains of the martian cratered upland terrains typically occur outside impact basins, previous studies (1,2) suggested that plains emplacement nevertheless may be influenced by multi-ring impact structures. This study examines the ridged plains units perched on the rims of the largest impact structures (termed here "rim plana") and proposes a mechanism for their formation.

Syrtis Major Planum (SMP) and Malea Planum (MP) each cap more than one million square kilometers of the massif rims of the Isidis and Hellas basins, respectively. The plains surfaces are significantly higher than the adjacent basin floors: SMP about 6 km above Isidis Planitia and MP about 5 km above Hellas (3,4), and are of comparable thickness. Although (5) derived a thickness of ~0.5 km for SMP units from elevation differences with cratered plains to the west, elevations inside the Isidis basin scarp to the south require a thickness of 1-2 km with a maximum of 2.5 km in order to bury the massif ring. Thickness estimates are poorly constrained in MP; however, burial of craters by lava units there suggests thicknesses of ~1 km. Consequently the rim plana roughly equal the lava volumes in the central basin plains of Isidis that cover ~1.1 million square kilometers and are estimated to be 1-2 km thick.

The rim plana on Mars represent a different style of plains volcanism from that observed on the Moon. The lunar mare basalts erupted along basin rings and emplaced in topographic lows contrast with the martian rim plana which form to one side of the basins several kilometers above the basin floor. Further unlike the central basin plains of the Moon, both SMP and MP have central, low relief volcanic shields (3,5) on extensions of nearby basin concentric graben. If an isostatic magma column controls the level of volcanic eruption (6), this requires a magma source depth of 30-40 km, near the base of the crust (7). Partial melt at such depths indicates a lithosphere beneath the rim plana thinner than the 125 km estimated from the distribution of graben around Isidis (8); therefore, local heating and lithospheric thinning before rim planum emplacement seems likely. Because a simple, global magmastatic head would favor mare-like eruptions in the lower basin interiors, the rim planum magma sources apparently had little access to such regions.

Two conditions are thus required for rim planum formation: first an underlying magma source must be established; second, a conduit must develop to the surface from this region. The coincidence of the rim plana with regions of intersecting weaknesses (1) and the alignment of graben trends with the planum shield structures supports conduit formation in lithospheric weaknesses around the basins. Fracturing occurs, however, at several points around the basin, whereas the rim plana are consistently offset to the same side of each basin, thereby suggesting some process controls the magma source location.

Reorientation of the martian lithosphere over an underlying, impact-derived hot-spot provides a possible mechanism for rim planum development (2). The formation of a sufficiently large basin cavity at impact can significantly alter the planetary moment of inertia (9) and can apply torque on the lithosphere to realign the new principle axis of inertia with respect to the the pole of rotation. Deformation along a low-viscosity zone at depth would allow movement of the lithosphere relative to the underlying mantle for some fraction of the total reorientation. The amount of reorientation is primarily limited by the preservation of rotational flattening in the lithosphere (10); the effects of isostatic adjustment (9); and basin fill reducing the mass anomaly of the basin. Assuming a 200:1 diameter-depth ratio basin after dynamic cavity collapse (on the order of the current Hellas aspect ratio), an impact the size of Hellas could significantly reorient the planet (figure). This reorientation, however, can be reduced by at least three factors: basin fill, reduced basin size and mantle uplift. In the first case, a Hellas-sized basin filled with even low-density sediments only causes significant reorientation if the preserved flattenning at that time was less than 1/3 the current value (figure). Present isostatic compensation of large basins indicates that the viscosity at depth was once lower; therefore, the amount of preserved flattening would have been lower in the past. In the second case, reorientation diminishes with basin size such that the effect of an Argyre-sized impact is only 1/2 that of the Hellas-sized impact above. Finally, the presence of a mantle uplift beneath the basin can be shown to be almost negligible because the effect of the uplift on reorientation is an order of magnitude smaller than that of the basin cavity.

A thermal anomaly initially beneath the basin develops from impact heating and impact-induced convection. While the majority of impact shock heating is concentrated near the surface, significant temperature increases have been modelled below 150 km (11), and the convection cell induced by basin cooling would extend to greater depths (12). For a shallow zone of decoupling (asthenospheric depths between ~100 and 150 km), reorientation after impact by 10-15° would place this hotspot beneath the basin rim, and local convection and lithospheric thinning would eventually develop partial melt at shallower depths. With flexure under central basin loads, lithospheric fracture creates volcanic conduits to this magma source. The similarity in plains ages might reflect a global condition favoring conduit formation analagous to lunar mare emplacement as proposed by (13), in which case the decrease in planum development with basin age would simply reflect the greater thermal decay of an older hotspot before the onset of volcanism.

If rim planum formation was common on Mars then similar volcanic units should occur near other martian basins. One possible candidate is Lunae Planum, which is comparable in thickness (14), size and age to SMP and MP. Although it does not exhibit shield volcanism, its location on the southwest massif rim of Chryse is consistent with the proposed rim planum model.

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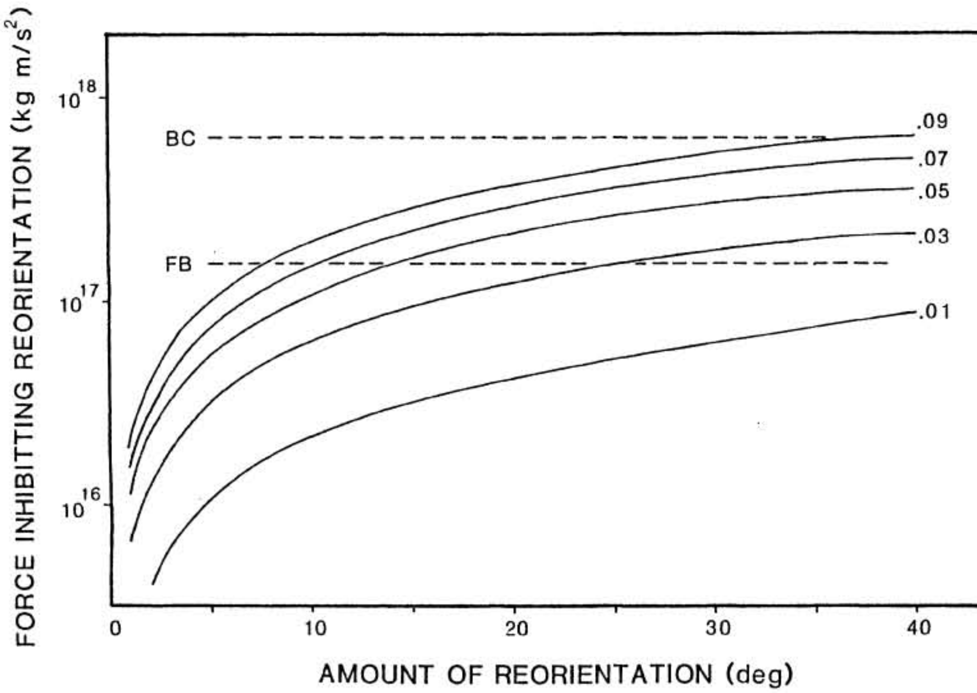

FIGURE: A plot of the counter-rotating force as a function of planetary rotation about an equatorial pole for 9%, 7%, 5%, 3% and 1% preserved dynamic flattening values; the current value is on the order of 10% (10). Reorientation proceeds until the applied basin torque matches the counteracting effect of preserved flattening. The reorienting force of a Hellas-sized basin cavity (BC) and a Hellas-sized basin with 1.8 gm/cm fill (FB) are shown for a basin latitude of 40°.