MARTIAN GRABENS AND PERMAFROST THICKNESS ON MARS. Cassandra J. Runyon* and Matthew P. Golombek, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058. *Present Address: Dept. of Geology, Southern Illinois University, Carbondale, IL 62901

Simple grabens have been used as probes of the subsurface mechanical structure of the moon (1) and Ganymede (2) based on a model developed for the grabens of Canyonlands National Park, Utah, which suggests that faults bounding grabens initiate at some subsurface mechanical discontinuity (3). This discontinuity separates crustal materials that react differently to similar tectonic stresses. Faults bounding grabens propagate upward from this interface at an angle that is dependent upon the crustal material to form simple grabens with similiar widths, similiar depths, and similiar spacings between members of a set.

There is abundant evidence on Mars for permafrost of 1-3 km thickness, depending upon the latitude (5). The similarity of cratering histories of Mars and the moon suggest that the outer few km of Mars, like the moon, consists of poorly consolidated ejecta underlain by extremely fractured and fragmented rock. As a result, the outer few km of Mars has considerable porosity enabling it to hold water in a liquid or solid state. Consequently, it is reasonable to suggest that the base of the permafrost zone may represent a mechanical discontinuity because materials whose pores are filled with frozen water are undoubtably stronger than their unfrozen counterparts. This suggested mechanical discontinuity between frozen and unfrozen material may be the mechanical discontinuity at which faults bounding grabens initiate. In this paper we test the hypothesis that faults bounding grabens on Mars intersect at the base of the permafrost.

It has been suggested that shallow troughs on Mars preferentially weather out to the base of the permafrost zone (6) somewhere between 1-3 km depth depending upon their location. Materials within the permafrost zone have been suggested to remain in a pristine state because they are frozen; materials below the permafrost would undergo alteration and cementation by the action of liquid water (6). Erosion of the trough was suggested to stop at the boundary because the cemented material would be more resistant to erosion. If this is true and if faults bounding grabens intersect at the base of the permafrost, an estimate of the dips of faults can be made by : 1) determining the depth of a trough using shadow lengths, 2) measuring the width of an adjacent fresh graben, and 3) calculating the angle of dip of faults bounding the grabens assuming they intersect at the base of the trough. Grabens are 0.5-2 km wide, troughs are 0.5-5 km deep, yielding calculated fault dips of 50°-85°. These dips are within the range of normal faults observed in different places on the earth. However, the majority of the measurements were taken in the Noctis Labyrinthus region and widely different fault dips were calculated for adjacent areas. Because the fault dip is dependent on the physical properties of the subsurface material and because most small areas presumably have fairly uniform subsurface physical properties, this large a range in fault dip is not probable. Instead, the fault dip would be expected to vary by no more than about $\pm 10^{o}$. This potential conflict between measured and expected fault dip can be resolved as follows. Faults bounding grabens are assumed to form with about $60^{o} \pm 10^{o}$ dips (the most common normal fault dip on the earth and moon) and to intersect at the base of the permafrost. Troughs weather out to the initial permafrost base because weathering slows when it reaches the cemented and altered material below the initial permafrost base thereby forming a sort of base level for many troughs. These troughs that are weathered out to the base of the initial permafrost zone yield calculated fault dips for nearby grabens of within the

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most probable range of $60^{o} \pm 10^{o}$. However, with time some troughs continue to weather out below the initial permafrost base because of possible further tectonic extension and because the permafrost around the trough locally deepens, adjusting to the new boundary conditions. These deeper troughs yield greater apparent fault dips for nearby grabens because faults bounding these grabens (that intersect at the shallower initial permafrost base) are assumed in the calculation to intersect at the deeper level. This accounts for the large range in calculated dip angles. Inasmuch as the range of fault dips is probably only about $60^{o} \pm 10^{o}$, the broad scatter in the calculated dips implies that many troughs in tectonically active areas weather out below the initial permafrost zone.

Other possible subsurface mechanical discontinuities were tested as potential discontinuities for the initiation of faults bounding grabens. An obvious possible subsurface mechanical discontinuity might be provided by the subsurface contact between different geologic units. To test this, about 700 systematic measurements of the width of all fresh grabens were made in 8 geologic units (from youngest smooth plains to oldest heavily cratered terrain) around Tharsis. If the subsurface contact of a particular geologic unit controlled the depth at which faults bounding grabens originated, then a systematic width might be expected for grabens in that particular unit. However, these measurements show no significant change in graben width relative to geologic unit indicating that subsurface geologic contacts do not control the initiation of graben faults. Furthermore, estimates of the thickness of volcanics around Tharsis (7, 8) were compared to the projected intersection depth of graben faults assuming probable 60° dips. These comparisons show that faults bounding martian grabens intersect well below the base of the volcanics. Therefore, the mechanical discontinuity that controls the initiation of graben faults is not provided by any subsurface geologic contact.

As a final check, we compared the projected intersection depth of faults bounding grabens to the theoretically determined permafrost base (5, 9). Assuming 60° dips, faults bounding grabens intersect 0.5-4 km below the surface, in excellent agreement with the expected 1-3 km thickness of permafrost on Mars. Graben widths do not systematically increase with latitude away from the equator as might be expected to result from a permafrost that thickens toward the poles. However, grabens around Tharsis only extend to $\pm 50^{o}$ latitude, a distance in which the theoretical permafrost only varies by 1 km (5, 9), which is probably less than the local or regional variability due to heat flow anomalies or other effects around Tharsis.

In conclusion, faults bounding grabens on Mars probably dip about $60^{o} \pm 10^{o}$ and intersect at the mechanical discontinuity provided by the base of the permafrost zone. Systematic measurement of grabens allows direct estimation of the permafrost thickness (0.5-4 km) on Mars.

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