EROSION ON LUNAR HIGHLAND SLOPES: IMPLICATIONS FOR PLANETARY LANDFORM ANALYSIS. R. A. Young, Department of Geological Sciences, SUNY, Geneseo, NY 14454

The established ages of the major lunar maria and detailed measurements of equilibrium and saturation cratering effects place finite limits on regolith thicknesses and production rates. These limits also define and demonstrate the effect of impact gardening on mare flows and volcanic landforms (1). Some specific effects of the documented postmare impact flux on highland slopes have been discussed by Young (2). One concept that should be emphasized is the contrast between gardening of younger horizontal mare surfaces and the effect of the equivalent flux on nearby highland slopes mantled with thicker regolith. The predictable consequences of downslope ballistic transport on highland slopes can help to explain some anomalous lunar landforms which are crucial to the interpretation of lunar geology, particularly the later stages of mare volcanism and associated tectonism. The natural tendency to view lunar features from a terrestrial perspective may have tended to obscure important information preserved in lunar landforms.

As described by Young (2) the effect of downslope ballistic sedimentation on lunar highland slopes produces a uniform "conveyor belt" type of downslope transport which is independent of slope length. This relatively uniform movement of the surface layer is especially characteristic of slopes during postmare time when large impacts have been few, and saturation cratering has progressed only to craters from 100m to 200m in diameter. Slow uniform downslope ballistic transport must be the dominant mode of slope erosion, because the regular debris aprons formed at the bases of slopes adjacent to the younger maria do not exhibit many irregular "talus cones" or distinct landslide features. Other processes, such as thermal creep, are assumed to be of lesser significance. The uniformity and efficiency of the process is attested to by the relatively smooth, regular appearance of lunar slopes and debris aprons as compared to the adjacent cratered mare surfaces. However, numerous young craters are clearly visible on enlarged photos of highland slopes, indicating that craters do not "obliterate" themselves on slopes as a result of the slumping and seismic effects that must accompany impact.

Studies of the genesis of mare ridges, the most widespread lunar (Martian and Mercurian?) features that continued to develop following the cessation of larger scale extrusive volcanism, have not produced a clear consensus among geologists (3,4,5,6,7,8,9). The ridges are closely associated with adjacent and colinear faults and graben structures that in many cases would be considered predominantly tensional features, especially those near basin margins like those in eastern and southern Mare Serenitatis. It seems likely that near-surface intrusions and extrusions have occurred along portions of many ridges (5,6) producing both broad arching and smaller scale extrusive features that have partially obscurred adjacent craters. However, the abrupt and distinctive morphologic change along ridge segments that cross the lower portions of highland slopes has resulted in attempts to invoke compression and thrust faulting as the major or dominant cause of mare ridge development. Certainly compressive stresses are likely to have existed in the central portions of subsided mare basins (3). This could have produced reverse faults of limited magnitude but is unlikely to have resulted in true thrust faulting of large magnitude (9).

Morphologic transitions along typical mare ridges on highland slopes, such as Dorsa Aldrovandi in Mare Serenitatis, are common in places where other geologic evidence clearly indicates tensional faulting, subsidence and late stage mare volcanism as being most compatible with the regional geology. The widespread evidence of subsidence and tensional faulting along mare margins is also compatible with evidence for late stage flooding of the centers of these subsiding mare basins from marginal vents. The existence of deep seated fractures along mare basin margins is predictable, as well as observable, in partially filled basins such as Mare Orientale.

Careful consideration of the gross effects of downslope ballistic transport across slope irregularities suggests that extrusive volcanism along fractures that intersect highland slopes is compatible with the observed morphological changes along ridges intersecting these slopes (Fig. 1). The greater flux of large objects during the early mare basin filling episodes would create some large-scale random slumping of highland material out onto the mare fill across the location of marginal fracture zones. Some deep seated circumferential fractures would intersect highland slopes, merely by coincidence. These circumstances would create conditions for late stage volcanism along fractures similar to the relationships shown on Fig. 1. Where lavas were extruded along fractures intersecting the lower segments of highland slopes fissure eruptions could have an initial form as depicted on Fig. 1a.

The long-term effect of downslope ballistic transport moves material down all slope segments and produces slow net erosion of all summit areas. However, one of the unique aspects of ballistic transport is that uniform transport (flux) conditions exist at <u>all</u> points on smooth slopes for <u>each</u> discrete crater size class. For each crater of a given size moving material downslope toward A (Fig. 1) from both sides, an equivalent impact at A will throw material out of the depression, back onto the slopes. This has the affect of slowing the filling of the linear depression by comparison with a simple gravitational mass wasting model. For larger craters ($\sim$20-100m) each impact at A will throw a significant amount of material <u>over</u> ridge B where it will eventually continue down slope C. Thus a quazi-equilibrium will be achieved so that moderate sized impacts (>10m) will result in the maintenance of a slowly filling depression by ejection of significant amounts of material over ridge B.

For slow rates of uniform downslope ballistic transport on thick regoliths the amount of material contributed to such a depression from the long highland slope (D) and the shorter slope on ridge B would be similar. However, initially, impacts into the thick highland regolith would be more effective than equivalent impacts into the solid lavas at B.

This morphologic form is transitional and will ultimately disappear as the cumulative flux increases through time. Preservation of such features merely attests to the slow uniform effect of impact gardening and downslope ballistic transport during the last 3 to 4 BY. If this type of ballistic transport mechanism did <u>not</u> exist on slopes it would be extremely difficult to explain the persistence of topographic irregularities on the same slopes where craters are being effectively removed and debris aprons have formed at the bases of slopes. Improved quantitative analyses of this type could provide alternative explanations of some planetary geologic landforms and eliminate some of the superficial disagreements resulting from oversimplifications or conflicting geologic interpretations of some very basic and important features and processes with no exact terrestrial counterparts.

(1) Schultz P.H. et al. (1977) Proc. Lunar Sci. Conf. 8th, p. 3539-3564. (2) Young R.A. (1976) Proc. Lunar Sci. Conf. 7th, p. 2801-2816. (3) Bryan W.B. (1973) Proc. Lunar Sci. 4th, p. 93-106. (4) Hodges C.A. (1973) Apollo 17 Prel. Sci. Report, p. 31-13 to 31-21. (5) Lucchitta B.K. (1977) Proc. Lunar Sci. Conf. 8th, p. 2691-2703. (6) Young R.A. et al. (1973) Apollo 17 Prel. Sci. Report, p. 31-1 to 31-11. (7) Howard K.A. and Muehlberger W.R. (1973) Apollo 17 Prel. Sci. Report, p. 31-22 to 31-24. (8) Scott D.H. (1973) Apollo 17 Prel. Sci. Report, p. 31-25 to 31-29. (9) Lucchitta B.K. (1976) Proc. Lunar Sci. Conf. 7th, p. 2761-2782.

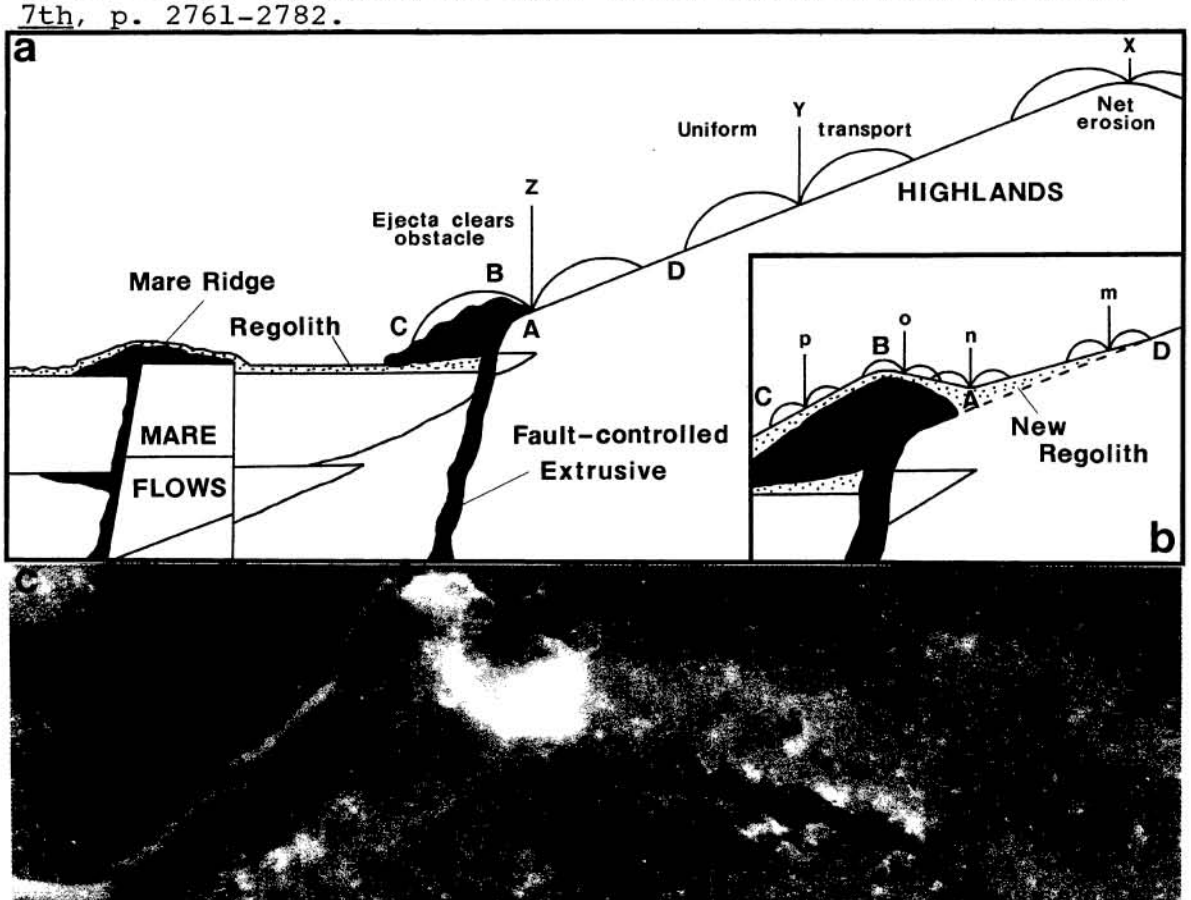

FIGURE 1: a. Initial condition after eruption of lavas at B. X,Y,Z illustrate effect of large impacts. b. Enlarged view of ridge B at later time showing effect of smaller impacts (m,n,o,p) c. Dorsa Aldrovandi in Mare Serenitatis showing highland area (h).