LUNAR RIMA PARRY IV: DIKE EMPLACEMENT PROCESSES AND CONSEQUENT VOLCANISM. J. W. Head[1], Jason S. Reed[2], and Catherine Weitz[1]. [1]Department of Geological Sciences, Brown University, Providence RI 02912, [2]Department of Geology, Marshall University, Huntingdon, WV 25755. James_Head_III@brown.edu.

Introduction: Linear and arcuate rilles (simple graben) have been interpreted to be linked to impact basin structure and to the emplacement of mare deposits in the basins via flexural deformation related to the mare deposit load [1]. Linear rilles are generally thought to represent deformation confined to the upper layers of the crust [2] where stresses are concentrated as rocks at deeper levels adjust viscously to long-term applied loads. Several linear rilles have associated volcanic (commonly pyroclastic) deposits [3,4]. We have interpreted several such graben as the surface manifestation of stress fields generated by dikes approaching the surface from great depths [5]. Here we use the Clementine multispectral data to investigate one such occurrence (Rima Parry V) to define the nature of the deposit and its extent, to compare it to other dark mantle deposits, and to assess the possibility that impact craters that have penetrated to depths below the top of the rille, might have exposed the top parts of dikes.

Data analysis: Rima Parry V (Fig. 1), about 50 km in length, is a linear rille that is part of a series of graben-like features that cut the floors and rims of the craters Fra Mauro, Parry, and Bonpland. These graben are not associated in terms of location or orientation with the graben interpreted to originate from loading and flexural deformation adjacent to the lunar maria [1]. The southern end of Rima Parry V occurs on the floor of Bonpland in the vicinity of Rima Parry VI; it extends NNE across the northern rim of Bonpland, descending to the floor of Fra Mauro, and continuing across the floor until it merges tangentially with the NNW trending Rima Parry I. As the structure extends onto the floor of Fra Mauro, the rille walls are obscured by deposits associated with a set of volcanic cones parallel to the western rille margin [6]. Between here and the intersection with Rima Parry I, the rille width is about 1.0 km, narrowing to about 900 m toward the end. Rilles in the vicinity of Rima Parry V cut the early Imbrian Fra Mauro Formation and are embayed by later Imbrian-aged maria [7].

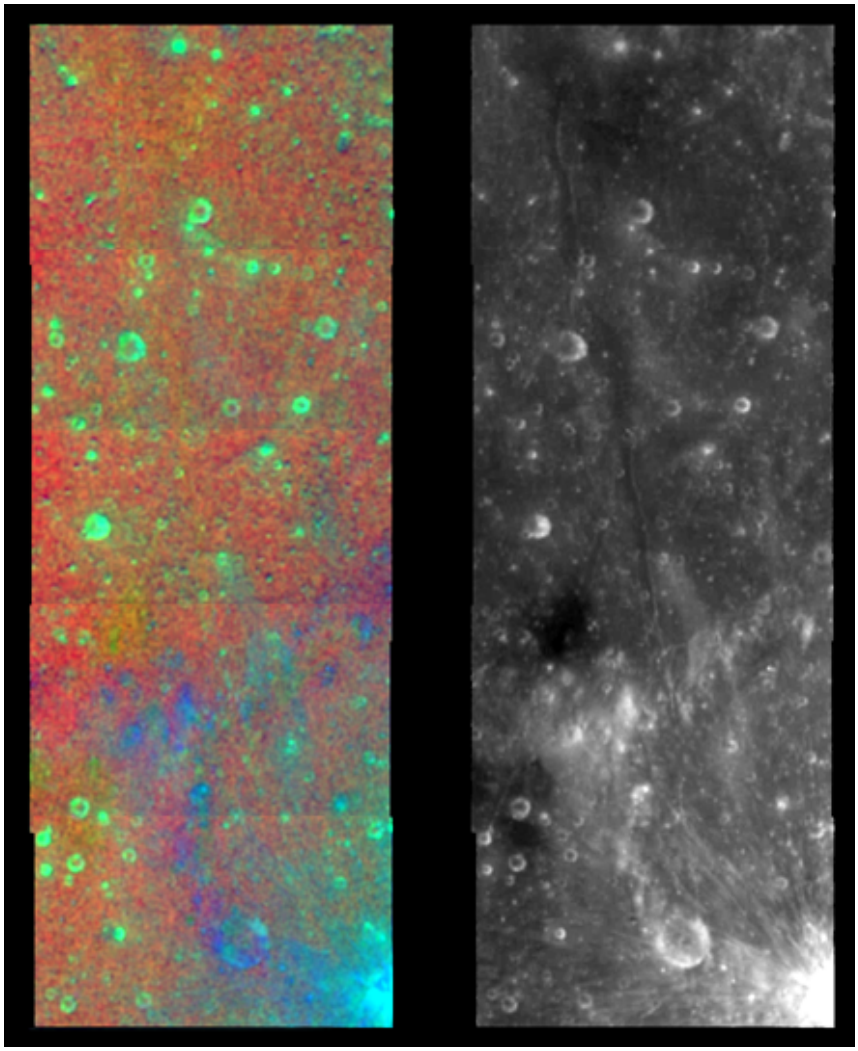

Figure 1. Clementine color image ratio and 750 nm mosaics of the Rima Parry region. The Rima Parry V volcanic cones are recognizable in the color ratio by their orange color while they have a low reflectance in the 750 nm image. The dark blue colors in the lower half of the image correspond to the rims of the craters Fra Mauro, Parry, and Bonpland and indicate the presence of highland material.

Rima Parry V displays a row of volcanic cones aligned parallel to the western margin of the graben. These, and associated deposits that mantle the rille topography, occur in a 10 km long segment located about midway along the rille extent (Fig. 1). Several of the cones are capped by craters and are interpreted to be of pyroclastic origin [7]. The deposits that obscure the rille interior are flatter, smoother and plains-like; these are of limited extent and are interpreted to be lava flows perhaps mixed with pyroclastic material. We interpret these occurrences to indicate the presence of magma just below the surface in the vicinity of the rille along a plane parallel to the rille. A combination of chemical evolution due to cooling of magma in the top of a dike and the migration of exsolved volatiles to shallow depths [8,9] could lead to positive buoyancy of part of the melt at the top of the dike, the propagation of fractures to the surface, and the eruption of pyroclastic materials and some small flows to flood the rille and form the cones.

The formation of surface graben should be a result of the penetration to shallow levels of steeply dipping dikes. Analysis of the surface and subsurface deformation expected as a result of such events provides a lower limit estimate of dike width of ~90-100 m. An additional estimate of the dike width was obtained from assessment of the horizontal surface strain per meter of dike width as a function of horizontal position above a shallow dike for various depths to the dike top. The distance between the strain maxima is inferred to be similar to the width of the graben, and for Rima Parry V, where the graben width is 1800 m, the implied depth to the dike top is ~650 m, and the implied dike ~170 m. We adopt a final estimate of 150 m from these values. This value is at the lower end of the 150-200 m mean dike widths estimated for dikes with sufficient driving pressure to cause near-surface dike intrusions from magma parent bodies at depths of 64-100 km [10]. On the basis of the hypothesis that the length of a dike which propagates through a great vertical distance is likely to be comparable to its vertical height, the length of Rima Parry V (about 50 km) and its tendency to narrow at both ends suggests that the parent magma body may lie at a minimum depth of 50 km. Thus, on the basis of these considerations, the presence of associated volcanic deposits, and the lack of significant effusive eruptions, we conclude that the characteristics of Rima Parry V are consistent with formation by a dike which propagated from great depth to near the lunar surface. Localized volcanic deposits along the linear rille Rima Parry V are interpreted to be the result of degassing and minor eruptions subsequent to magma emplacement at shallow depth.

Two Clementine orbits cover Rima Parry: Revs 42 and 175. Rev 175 is higher resolution (144 m/pixel) but the phase angle is only 9° and images cannot be calibrated properly below 15°. Rev 42, at 117 m/pixel and 24° phase angle, was used for this analysis (Fig. 1, 2). The analysis reveals the following:

(1) The rims of the craters Parry, Fra Mauro, and Bonpland are recognizable in the image data and one sees highland spectra on steep slopes. The spectra show anorthositic (Highlands 2) and noritic (Highlands 1) affinities. The fresh crater on the southern rim of Parry crater has a very high reflectance and a noritic signature. Another larger crater on the rim of Parry-Bonpland is a mixture of norite and anorthosite. These data indicate that Parry, Fra Mauro, and Bonpland all exposed mixtures of anorthositic crust and Mg-rich materials. A fresh highland signature is observed only where there is mass wasting or exposure by younger craters.

(2) Most of region has an orange color and fresh craters into this unit have noritic signatures similar to that seen on larger crater rims but much lower in reflectance.

(3) The Rima Parry rilles are spectrally the same as adjacent smooth plains. Craters penetrating into the rille also show the same signature and there is no mare visible along the rille.

(4) The cones of Rima Parry V have spectra of volcanic glasses, similar to those of the Aristarchus Plateau dark mantle deposit [11,12]. Also observed is a glass-rich deposit interpreted to be of pyroclastic origin around the cones. Another deposit located on the floor of Bonpland, and offset from rille also indicates the presence of dark mantle materials.

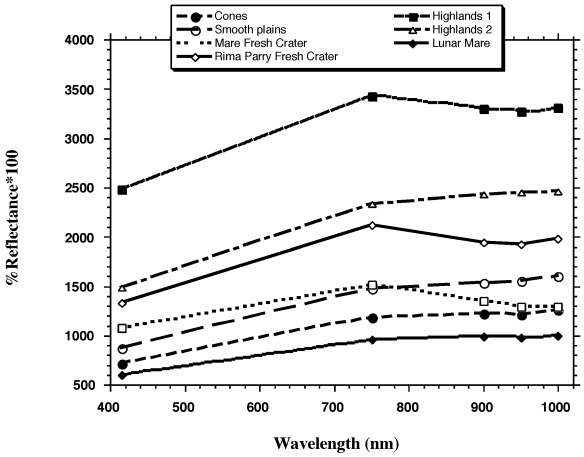

Figure 2. Spectra taken from various geologic units in the Rima Parry region. Craters in the region indicate the presence of either noritic or anorthositic rocks. Fresh and mature mare spectra taken from the Marius Hills region do not match any of the spectra from Rima Parry. The volcanic cones have spectra characteristic of the volcanic beads found in dark mantle deposits.

References: 1) S. Solomon and J. Head, Rev. Geophys. Space Phys, 18, 107-141, 1980. 2) M. Golombek, J. Geophys. Res., 84, 4657-4666, 1979. 3) P. Schultz, Moon Morphology, University of Texas Press, 626 p., 1972. 4) J. Head, Lunar volcanism in space and time, Rev. Geophys. Space Phys, 14, 265-300, 1976. 5) L. Wilson and J. Head, PSS, 41, 719-727, 1993. 6) D. Wilhelms, U.S.G.S. Prof. Paper 1348, 302 p., 1987. 7) Lucchitta and Watkins, Proc. Lunar Planet. Sci. Conf. 9th, 3459-3472, 1978. 8) L. Wilson and J. Head, J. Geophys. Res., 86, 2971-3001, 1981. 9) J. Head and L. Wilson, Proc. Lunar Planet. Sci. Conf. 10th, 2861-2897, 1979. 10) J. Head and L. Wilson, Geochim. Cosmochim. Acta., 56, 2155-2175, 1992. 11) C. Weitz et al., Lunar regional dark mantle deposits: Geologic, multispectral, and modeling studies, Submitted to J. Geophys. Res., 1998. 12) C. Weitz and J. Head, LPSC 29, 1998.