ORIGIN OF CENTRAL PEAKS AND PEAK RINGS: EVIDENCE FROM PEAK-RING BASINS ON MOON, MARS, AND MERCURY. James W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912.

Central peaks are an important morphological and structural feature of virtually all fresh craters above a certain threshold diameter on the Moon, Mars, and Mercury. Depth/diameter relationships for fresh lunar craters and basins and associated morphologic features[1,2] show general trends in occurrence that are similar for Mars[3] and Mercury[4]: 1) central peaks are not abundant below a certain diameter; 2) they appear and become a prominent part of all fresh impact craters at intermediate crater diameters; 3) at diameters greater than about 100 km, a ring of peaks is often seen surrounding the central peak, forming a central peak basin[5]; 4) at larger diameters, the centralmost peaks disappear, leaving a peak ring, and forming a peak-ring basin[5]; 5) at even larger diameters, a third ring is often added to form a multi-ring basin[5,6].

The origin of central peaks has long been a matter of controversy. Terrestrial field and sample investigations have demonstrated an impact origin; however, major uncertainties remain concerning the actual mechanism of formation. Several researchers[7,8] have proposed that central uplift is a consequence of centripetal collapse of the walls of the crater after the final excavation of material from the cavity. These theories emphasize the role of gravity-induced failure of the transient cavity operating during the modification stage of the cratering event. Hartmann[9] noted differences in diameter of occurrence for peaks and peak rings on the Moon, Mars, and Earth. He concluded that gravity was the major factor controlling the formation of these features and that interplanet variations were directly related to gravitational field strength. An alternative view holds that central uplift occurs during the excavation stage of the cratering event, initiated by high stresses associated with the interaction of shock and rarefaction waves and the target surface[10]. In this case, central peaks are related to crater-forming energy[11], rather than post-formational gravitational collapse and gravitationally controlled uplift. The purpose of this study was to examine the characteristics and occurrence of craters that contain central peaks or peak rings on the Moon, Mars, and Mercury, in order to determine whether peak-ring and central peak formation is due to gravitational potential energy, or kinetic energy of impact.

Previously, much emphasis had been placed on the onset diameter and relative abundance of central peaks on the Moon and Mercury in terms of the gravity hypothesis[4]. Recent studies have shown that other factors, such as substrate characteristics[12], minor crater wall erosion[13], and modal impact velocity[5,14], are significant in determining the onset diameter of central peaks, and that no clearcut interplanetary correlation exists between gravity and onset diameter. Therefore, attention is here focused on diameter ranges where central peaks form in the majority of fresh craters.

Moon - Wood[11] has shown a linear relationship between central peak height and crater diameter for the Moon and proposed that central peaks are related to crater-forming energy. Central peak basins occur over a range of 140-175 km and peak-ring basins 175-440 km[5,15] (Fig. 1). A plot of the rim crest diameter (D_{rc}) and peak-ring diameter (D_{pr}) for 12 lunar examples shows a linear

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relationship between these two parameters[16,17] ($D_{pr}=0.56D_{rc}-17.55$).

Mars - Martian surface gravity is about a factor of 2 greater than the Moon. A similar progression of interior morphologies is observed[3,14]. No data are presently available on central peak heights; central peak basin diameters range from 135-150 km (Fig. 1). A linear relationship is observed between crater diameter and peak-ring diameter (n=14) ($D_{pr}=0.53D_{rc}-7.54$).

Mercury - Surface gravity is similar to Mars, but modal impact velocity is higher than Moon and Mars[5,18]. A similar progression of interior morphologies[4] is observed and preliminary data suggest central peak heights are similar to the Moon[4,19]. Central peak basin diameters range from 90-130 km, peak-ring basins from 120-150 km (Fig. 1). A linear relationship is observed between crater diameter and peak-ring diameter (n=33) ($D_{pr}=0.51D_{rc}-5.65$).

Discussion - Combining diameter data for central peak basins and peak-ring basins[20] for the three planets (Fig. 2) shows that the linear relationship is essentially the same for all 3 planets. The similarity of this relationship on three planets whose maximum gravity difference is more than a factor of 2 argures against gravity as a major factor in the formation of peak rings. It has been shown by Gault and others[4] that rim crest diameter (D_{rc}) shows an exponential relationship to the kinetic energy of impact. The distinctive linear correlation of rim crest diameter and peak-ring diameter argues strongly that peak-ring diameter shows a similar relationship to the kinetic energy of impact[17]. In addition, a major part of the differences in onset diameters of central peak basins and peak ring basins on the planets (Fig. 1) seems readily explained by differing modal impact velocities, with higher impact velocities producing onset at lower diameters. For example, a projectile of a given size that would form a very large crater on the Moon and Mars, might form a central peak basin or peak-ring basin on Mercury[5] because of higher modal impact velocity[18] and higher kinetic energy.

Conclusions - 1) No evidence is found to support an origin for central peaks and peak rings dominated by gravitational potential energy. This conclusion is supported by (a) the similarity of rim crest diameter/peak-ring diameter relationships in peak-ring basins on Moon, Mars, and Mercury where gravity differs by greater than a factor of 2; and (b) preliminary data on Mercury central peak heights showing similarities to the Moon[4,19]. 2) Abundant evidence is found to support a kinetic energy-related origin for central peaks and peak rings, including the facts that (a) lunar central peak heights show a linear relation with crater diameter[11], (b) peak rings and crater diameters are linearly related on the Moon, Mars, and Mercury, and (c) the relationship of crater diameter and peak-ring diameters on the 3 planets are identical despite variations in surface gravity and other factors. 3) The onset of central peak basins and peak-ring basins on Mercury at lower diameters than on Moon and Mars is consistent with higher modal impact velocities for Mercury and a kinetic energy-related origin for central peaks and peak rings. 4) These observations suggest that central peak rings form when impacts produce sufficient energy to eject material from the interior of the central peak region[1]. Excavation of the central region may continue and produce a central depression at large diameters.

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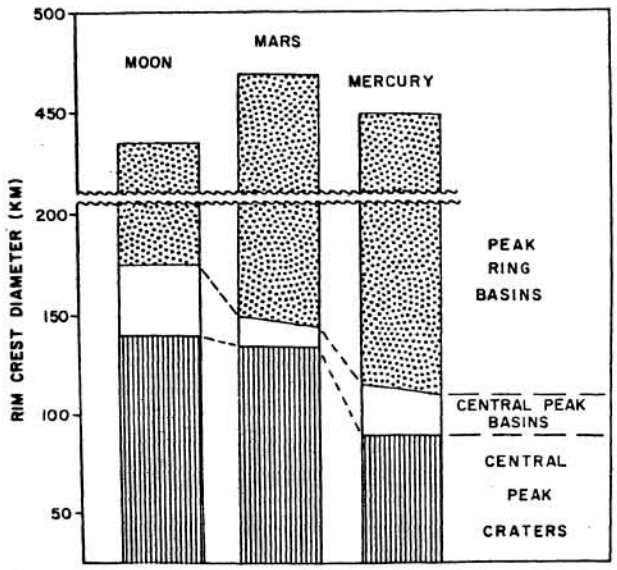

Fig. 1

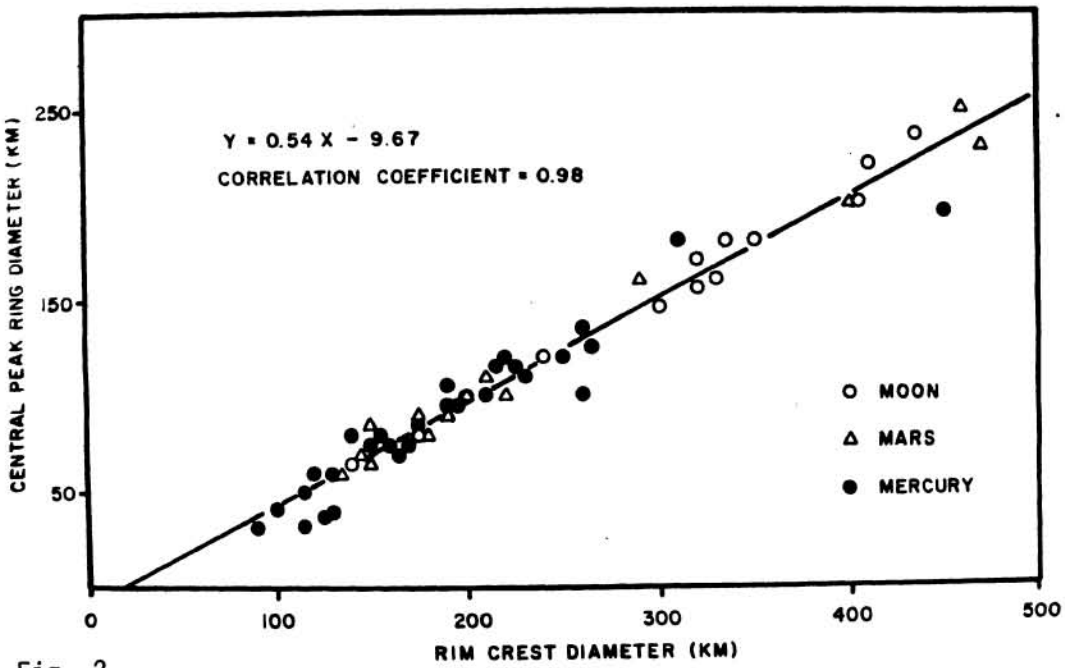

Fig. 2