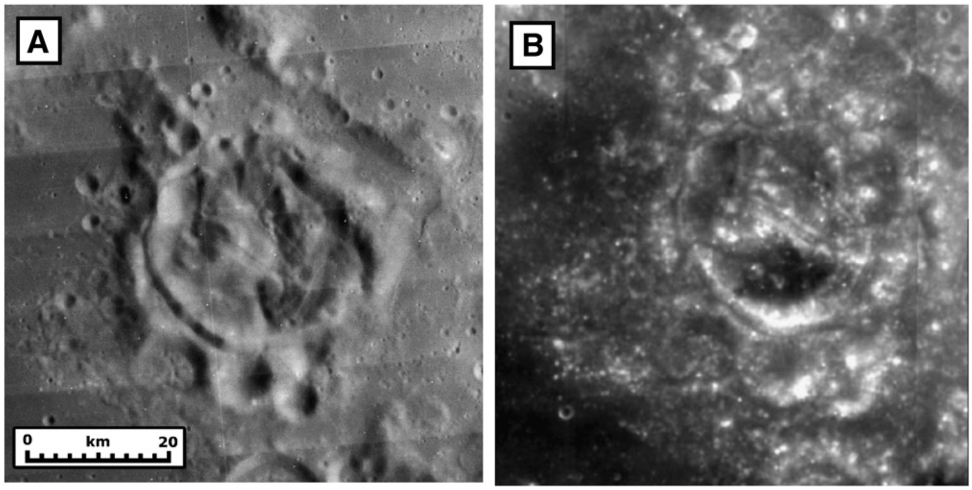

Fig. 4. Gaudibert floor-fractured crater on the Moon, ~33 km in diameter. (A) Lunar Orbiter 4 image (LO-IV-072H); illumination geometry emphasizes morphology. (B) Clementine image; illumination geometry emphasizes albedo differences. Compare floor-fractured craters on the Moon (Fig. 4A) and Mercury (Fig. 3B).

near the terminator (optimal illumination conditions) of one floor-fractured crater in images from the first MESSENGER flyby suggests that others may be detected under more favorable illumination conditions. As yet, however, no large, complex, floor-fractured craters such as the lunar crater Gassendi (Fig. 2) have been observed on Mercury. The general global contractional tectonic environment (Solomon et al., 2008) may mean that shallow crustal stress environments and principal stress orientations favoring shallow sill-like intrusions may have been less common on Mercury than on the Moon. Global image and altimetry coverage provided by future MESSENGER and BepiColombo (Benkhoff et al., in press) mission operations will help to address these questions.

3. Concentric graben on the floor of Raditladi basin

MESSENGER images also revealed fractures and graben on the floor of the ~250-km-diameter Raditladi basin (Fig. 5) (see also Prockter et al., 2008; Watters et al., 2009b-this issue). Unlike typically broad patterns of floor fractures on the Moon (Schultz, 1976), as exemplified by the 110-diameter crater Gassendi (Fig. 2), the floor fracturing in Raditladi is focused within the inner ring and consists of a series of narrow concentric graben structures with no direct evidence at current resolution for an unusually shallow crater floor or associated vents or dark-halo craters. Two small, elongated craters that may be volcanic vents are seen on the northern part of the crater floor (Fig. 5B, C). The peak ring is offset to the northwest from the center of the crater defined by the crater rim crest. The center of the ring of graben, however, is located close to the center of the crater defined by the crater rim crest and is offset toward the southeast from the center of the peak ring.

One possible interpretation is that a sill-like intrusion and related floor fracturing were limited to a zone within the basin peak ring, rather than spread across the entire crater floor as is the case in Gassendi (Fig. 2) or the lunar crater Taruntius (Wichman and Schultz, 1996). If this is the case, any uplift would have to be very limited, as the graben do not show the asymmetry (interior sides of graben higher than exterior sides) that are usually seen in marginal graben in shallow lunar floor-fractured craters such as Taruntius and Gassendi. On the basis of terrestrial crater structure, Schultz (1976) and Wichman and Schultz (1996) considered the base of the floor breccia lens to be a likely candidate for the density-contrast horizon at which sills intrude in lunar craters. The distribution of breccia lenses may be quite different in complex craters than larger peak-ring basins. For example, the breccia lens might be interrupted by the peak ring, or deeper in the peak-ring interior, and this geometry might cause intrusion of sills to be manifested differently in peak-ring basins.

Another possible interpretation for the graben structure is that it represents the surface manifestation of magmatic intrusions known as ring dikes or cone sheets (e.g., Schirnick et al., 1999). Ring dikes on Earth consist of one or more sets of concentric fracture systems along which lavas intrude and surface volcanic features often form. Ring dikes form a magma-filled cylinder around a block of country rock. Cone sheets are thin intrusive sheets a few meters thick that expand upwards and outwards in cones and converge towards a common source at depth, usually a magma reservoir. Ring dikes and cone sheets often occur together, as exemplified by the classic examples on the islands of Mull and Skye, Scotland. Anderson (1936) studied the dynamics of formation of cone sheets and ring dikes, showed how displacements due to a point dilation are modified when the point is near a planar free surface, and treated the case for strain associated with the "point push." Specifically, an upward point push at a specific depth could lead to the formation of cone sheets, while a downward point push at a corresponding depth could lead to the formation of ring dikes (Anderson, 1936). More recent analyses (Le Bas, 1971; Phillips, 1974) have explored the geology and dynamics of emplacement of ring dikes and cone sheets in terrestrial environments. Most ring dikes and cone sheets on Earth are exposed by hundreds of meters of erosion, and thus the surface manifestation of these features in a fresh unweathered environment is not known. However, on the basis of the dynamics of intrusion (Anderson, 1936; Le Bas, 1971; Phillips, 1974), it is likely that near-surface intrusions of both cone sheets and ring dikes would result in concentric graben. Thus, a possible interpretation of the concentric graben on the floor of the Raditladi basin is that they represent the surface manifestation of ring dikes and/or cone sheets, forming above a magma reservoir. This configuration would differ in geometry from the traditional sill formation thought to be responsible for lunar floor-fractured craters (e.g., Schultz, 1976).

The Raditladi crater floor graben could also be related to late-stage tectonic modification and uplift of the basin floor (Watters et al., 2009a,b-this issue), rather than to a sill or a magma reservoir and ring dikes/cone sheets. Detailed models have not yet been developed for any of these processes in the Raditladi basin. Any hypothesis should explain the slight off-center location of the peak ring (relative to the basin rim crest), the central location of the concentric graben structure (Fig. 5) (compared with the basin rim crest), and the floor plains of presumed volcanic origin (Watters et al., 2009a,b-this issue).