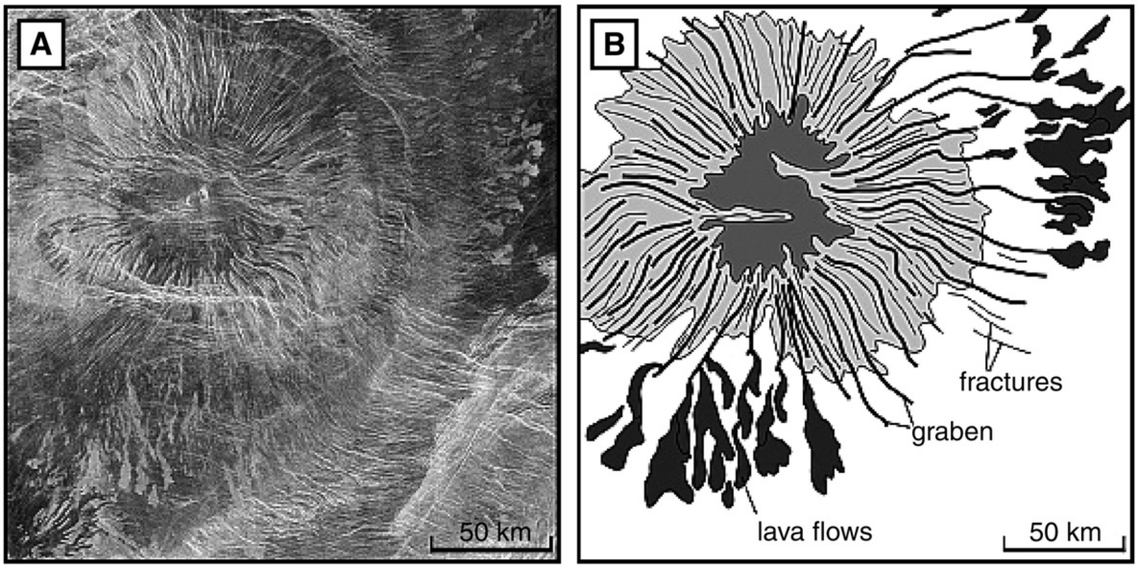

Fig. 10. Typical example of a nova (14°S, 164°E) showing radial structure of graben and fractures and related lava flows generally emanating from the ends of the graben. These types of relationships support the interpretation of many novae as surface manifestations of shallow dike emplacement events. (A) Portion of Magellan radar image C1-MIDR 15S163.101. (B) Sketch map. After Krassilnikov and Head (2003).

lithosphere, a decrease in the ability of mantle convective patterns to disrupt the lithosphere, a decrease in the amount of mantle partial melt, and a decrease in the ability of dikes to reach the surface (e.g., Head and Wilson, 1992). These general trends would decrease the likelihood of shallow magma reservoirs and associated radial dike swarms. In such a global tectonic environment, however, impact craters and basins can cause perturbations to both the stress state and the thermal structure. The formation of an impact feature relieves pre-existing stress within the crater and a more extensive zone of mechanical damage (e.g., Freed et al., 2009-this issue) and heats the interior through the conversion of impact kinetic energy to heat and uplift of isotherms during basin collapse (e.g., Bratt et al., 1985). A large basin may therefore provide an effective focus for mantle upwelling, melt generation, magma ascent, and near-surface extension (e.g., Elkins-Tanton et al., 2004; Ghods and Arkani-Hamed, 2007).

In summary, we find that the hypothesis of a magmatic origin for Pantheon Fossae is worthy of further investigation. Specific simulations of the development of such a feature should include the formation of the Caloris basin, the response of the crust and mantle to basin formation, the generation and ascent of magma, and the near-surface stress field though time, and particular attention should be paid to why the history of the Caloris basin has differed from basins of comparable size on the Moon and other terrestrial planets. Given the context of an overall model for Caloris, formation of a shallow magma reservoir would result in radial dike propagation; the symmetry of the dikes is consistent with formation in the center of a circular basin where stresses are most likely to be horizontally isotropic. Buffered and unbuffered reservoir conditions (Parfitt and Head, 1993) can plausibly account for the two radial ranges of graben. These predictions can be further tested with altimeter and gravity observations, high-resolution imaging, and searches for analogous features in previously unseen areas of Mercury.

5. Discussion and conclusions

The first MESSENGER flyby has confirmed Mariner 10 interpretations that volcanism was responsible for the formation of many occurrences of regional plains on Mercury (Strom et al., 1975; Robinson and Lucey, 1997). The view of the area imaged for the first time during the MESSENGER flyby (an additional 21% of the surface and the full Caloris basin interior) has served to underline the paucity of occurrences of extensional deformation that might reflect subsurface magmatic events. We describe three occurrences: (1) a floor-fractured crater on the margin of plains interpreted to be of volcanic origin (Head et al., 2008, 2009-this issue) that appears to be formed by shallow sill intrusion and laccolith formation; (2) a set of concentric graben inside the central peak ring of the ~250-km-diameter crater Raditladi (Prockter et al., 2008) that could be the surface expression of cone sheets and ring dikes, or alternatively of post-infill uplift of the central basin floor; (3) the Pantheon Fossae complex, a ~350-km-diameter radial graben swarm located in the center of the Caloris basin, which has been ascribed to several processes. We examine the similarity of this last feature to radial dike swarms known or interpreted on other planets and conclude that this hypothesis merits further testing as an origin for this structure. New data to be obtained by the MESSENGER and BepiColombo missions will be required to distinguish among the several hypotheses for Pantheon Fossae. Higher-resolution data taken at different solar illumination geometries will permit further documentation of its geometry and its relationship to Caloris basin fill, associated tectonic features, and Apollodorus crater. These data will enable us to address further the questions: What is the origin of the graben and are there any vent-related features and structures? Why are the graben so symmetrically arrayed? Why is the only known occurrence of such a structure in the center of the Caloris basin? Is the location of Apollodorus crater coincidental or genetically related to Pantheon Fossae?

The scarcity of extensional features on Mercury, and the location of those that are observed in impact basin interiors and adjacent to plains of volcanic origin, supports other observations of the tectonic and volcanic style of Mercury (Wilson and Head, 2008). The emerging picture of the volcanic style of Mercury is similar to that of the Moon, the other small one-plate planet (Wilson and Head, 2008): there are no major shield volcanoes, shallow magma reservoirs are rare, and there is little evidence of broadly distributed mantle upwelling associated with deformation of the surface or shallow volcanic sources. Because of the dominance of contractional deformation, evidence for shallow intrusions (e.g., dikes and sills) may be even rarer on Mercury than on the Moon, and such shallow intrusive events may require special circumstances (large crater or basin formation) to provide regional thermal and stress environments that deviate from the general global trend. These hypotheses can be further tested with new MESSENGER and BepiColombo data.