eruption onto the surface and emplacement and solidification of magma as effusive lava flows or explosive tephra. The first flyby of Mercury by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft on 14 January 2008 obtained images of 21% of the surface not seen by the Mariner 10 spacecraft (Solomon et al., 2008), including the remainder of the Caloris basin and new regions near the terminator showing details of the nature of smooth and intercrater plains. Images from MESSENGER's Mercury Dual Imaging System (MDIS) have helped to address and resolve a series of questions related to the existence, nature, and distribution of magmatism (volcanism and plutonism) that have been largely outstanding since the end of the Mariner 10 mission in 1975. In separate contributions, we have outlined the evidence that supports and confirms earlier hypotheses from Mariner 10 data that volcanism was important in shaping the surface of Mercury; this new evidence includes the presence of volcanic vents, a shield-like structure, spectrally distinct plains embaying adjacent units, and spectrally distinct mantling deposits interpreted to be of pyroclastic origin (Head et al., 2008; Robinson et al., 2008; Murchie et al., 2008; Blewett et al., 2009-this issue; Kerber et al., 2009-this issue; Head et al., 2009-this issue). In this contribution we assess the evidence for the surface manifestation of intrusive magmatic activity on the basis of the MDIS images obtained during the first flyby.

Magma reaches the surface through propagating magma-filled cracks (dikes), its rise driven by overburden pressures, magma overpressure, and thermal and chemical buoyancy variations (Fig. 1). On the Moon, where dikes propagate from great depths and eruptions were infrequent even during the peak of mare volcanism, eruptions tend to be characterized by high rates of ascent and eruption (Head and Wilson, 1992). Shallow magma reservoirs, commonly formed by multiple dike intrusions at a zone of neutral buoyancy, are uncommon (Head and Wilson, 1991). Moderate- to large-diameter volcanic edifices, built from multiple phases of inflation, lateral and vertical dike emplacement events, and eruptions from shallow magma reservoirs, are not observed on the Moon (Head and Wilson, 1991) but are common on the Earth, Venus, and Mars (Head et al., 1992; Carr, 2006). Mercury, like the Moon, is dominated by extensive plains units, a few visible volcanic vents, but (as yet) no major volcanic edifices on the scale of the Tharsis Montes on Mars (Head et al., 2008, 2009-this issue), a style and surface character typical of small one-plate planetary bodies for which the lithosphere thickened comparatively rapidly early in the planet's history (Solomon, 1977, 1978). On the Moon, the surface manifestation of intrusive magmatic activity is found in graben, often marking the presence of dikes intruding to near the surface, and their associated features (Fig. 1) (Head and Wilson, 1993), and in floor-fractured craters, interpreted to be the surface manifestation of sill formation beneath crater floors (Schultz, 1976). Here we examine occurrences of such features in impact craters and basins on Mercury documented in MDIS images, and we explore the implications of these occurrences for the presence and significance of plutonic activity on the innermost planet.

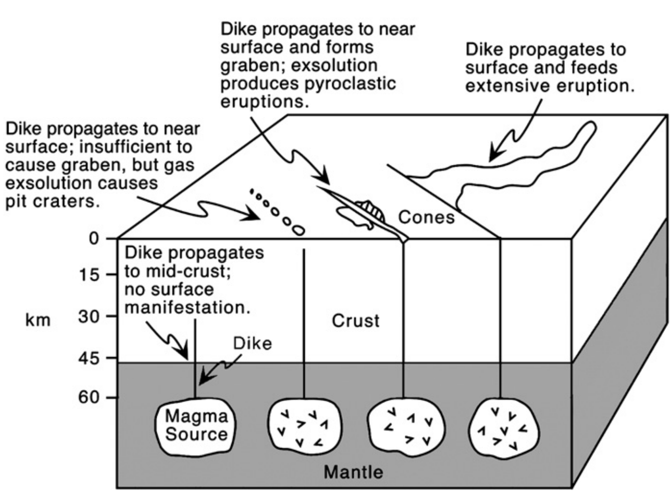


**Fig. 1.** Relationship of dikes to their surface environment, showing several different manifestation of dikes as they propagate from mantle magma reservoirs into the crust, approach the surface, and stall or erupt. After Wilson and Head (2008).

## 2. Floor-fractured craters

Despite the paucity of shallow magma reservoirs on the Moon, there is evidence for local sill formation, caused by lateral intrusion of magma from vertically propagating dikes at density or material–property boundaries to create horizontal lenses of magma in the shallow crust. The most compelling evidence for shallow sill formation is the presence of floor-fractured craters, impact craters whose floors have been fractured, uplifted, and often partially flooded by lava flows (Schultz, 1976) (Fig. 2). Dikes intruding into the shallow crust are interpreted to have formed sill-like bodies preferentially along the base of the low-density brecciated zone in the crater interior. On the Moon, floor-fractured craters occur predominantly along the margins of the lunar mare basins. Such craters often have moats around the uplifted interior floor. Other associated features include dark-halo craters located along the floor fractures, the most well-known example of which is the crater Alphonsus (Head and Wilson, 1979). Schultz (1976) identified seven different classes of floor-fractured craters on the Moon, related to both the initial geometry of the crater and to the stages in the evolution of its modification. An alternative explanation for floor fracturing is viscous or viscoelastic relaxation of topographic relief, enhanced by higher than normal subsurface temperatures in the vicinity of impact basins (Hall et al., 1981). The most detailed models of such a mechanism, however, cannot account for floor uplift and fracturing for craters smaller than about 100 km in diameter (Dombard and Gillis, 2001).

Although Mariner 10 image resolution and illumination geometries were not the most favorable for detection and documentation of floor-fractured craters on Mercury, Schultz (1977) reviewed candidate examples of endogenic modification of impact craters on Mercury and found evidence for crater floor units and structures of possible volcanic origin, as well as for uplift and possible fracturing. MESSENGER's first Mercury flyby revealed a single example of a classic lunar-like floor-fractured crater (Figs. 3 and 4) in the vicinity of the terminator; although for MESSENGER, too, the illumination geometry was less than favorable for the detection of floor-fractured craters over much of the rest of the area imaged. This ~35-km-diameter floor-fractured crater (Fig. 3B), briefly described by Head et al. (2008), is located near the margins of extensive deposits of smooth and intercrater plains that have been interpreted to be of volcanic origin by Robinson et al. (2008) and Head et al. (2009-this issue) (compare with the perspective view of Gassendi, Fig. 2 top and lower left). Relatively fresh impact craters of comparable size are characterized by raised rims, terraced walls, flat floors, and central peaks (Pike, 1988) (Fig. 3B). In contrast, the interior of this crater (Fig. 3B, C) appears highly modified, with the south–southeastern wall slumped inward, wall terraces indistinct and obscured, and the floor of the crater generally appearing shallower than for the fresh example. The exterior of the crater is clearly embayed on its western margins by smooth plains (Fig. 3B, C).

Although no concentric fractures and moats typical of large lunar floor-fractured craters are seen, the most distinctive parts of the crater interior are two dome-like or plateau-like features located on the eastern and western parts of the crater floor. These dome-like features are unlike central peaks in their morphology and position (compare Fig. 3B, C with Fig. 3A). Peak rings form mountains and hummocks surrounding the crater center but do not occur in fresh craters of this size (Pike, 1988) and are morphologically dissimilar to these features