



Planetary Analog Sites:

3. Pit Craters

Key Concept: The distribution of pit craters can be interpreted to be the surface expression of dikes in volcanic areas, and can be used to help define the internal structure of a volcano. In addition, pit craters may be “skylights” into lava tubes, and thus have attracted interest as possible shelters for astronauts on the surface of the Moon, or as possible sites for astrobiological activity on Mars.

Hawaii’s Pit Craters – Insights into Subsurface Structure

The upper part of Kilauea’s east Rift Zone is marked by a very prominent line of craters. These craters, called “pit craters” are derived purely by collapse, as evidenced by the lack of any build-up of materials around their rims. Eruptive vents occasionally open within or across these pit craters, however, and lava often ponds in them. These craters are collapse features that are associated with some type of long-lived conduit that runs the length of the rift zone. In one mechanism suggested by Walker (1988), the craters form by the upward stopping of a void that develops in the roof of this large conduit. A fine example of a pit crater is Devil’s Throat crater (Fig. 1), which formed sometime in the late 1880s and initially consisted of a relatively small opening in the ground that has grown over more than a century to be a pit ~40 m in diameter.



Fig. 1: A pit crater on Chain of Craters Road, Hawaii. (left) Air photograph of Devil’s Throat pit crater, which is ~40 m in diameter and is believed to have formed in the 1880s. Arrow points to the location of the field photo at right; (right) Ground photo of rim of Devil’s Throat, showing the sequence of lava flows within which the pit formed.

A second pit-crater formation mechanism was proposed by Okubo and Martel (1998). They considered the fact that when a dike propagates through a volcano, a pair of planar fractures extends upward from the top edge of the dike in a V-like pattern. The angle of this “V” is constant, which means that when the dike is deep the fractures will intersect the surface far from each other but when the dike is shallow they will intersect close by (Fig. 2). The triangular segment of rock between the fractures will want to fall, but when the fractures are far apart it means that they have a lot of surface area and therefore a lot of friction. When the fractures are close, however, they provide less surface area and less friction and so tend to collapse into the conduit. The key observation made by Okubo and Martel (1998) was that indeed pairs of ground fractures often form hourglass-like traces, and pit craters such as Devil’s Throat commonly occur at the point of closest approach.

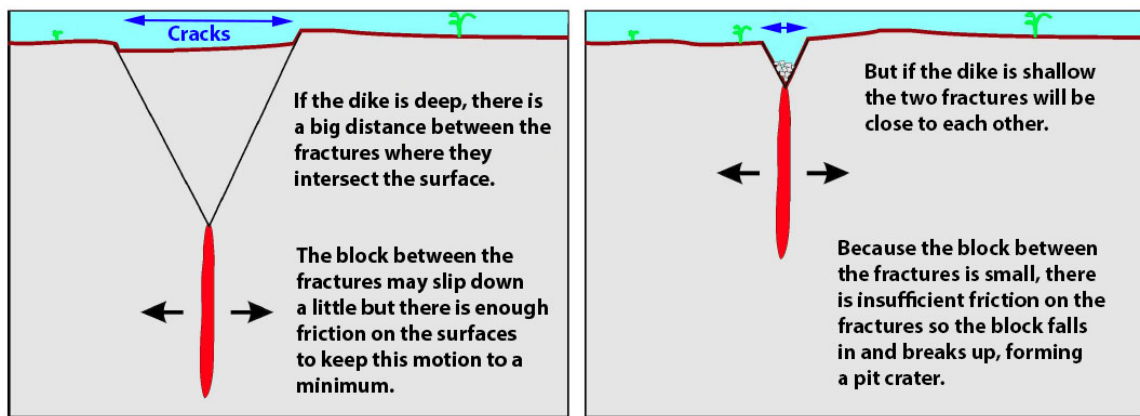


Fig. 2: Mechanism to produce a pit crater from dike-generated fractures, after Okubo and Martel (1998).

Planetary Pit Craters

Pit craters are common features on the planets and occur in nearly all terrains that were shaped primarily by tectonism and/or volcanism. One of the best examples yet detected (Fig. 3) lies on the southeastern flank of the volcano Pavonis Mons. Numerous examples have been documented for the Tharsis volcanoes on Mars (Wyrick *et al.*, 2004; Cushing *et al.*, 2007). Individual pit craters on Mars range from less than 100 m to more than 6 km in diameter and frequently occur in linear or curvilinear chains. These pits are generally bowl shaped, and their floors, which may be flat or concave-upwards in their centers. As with their terrestrial counterparts, very few of these planetary pits appear to have been the source of lava on the surface, although a few rare examples (e.g., Fig. 4) do exist.

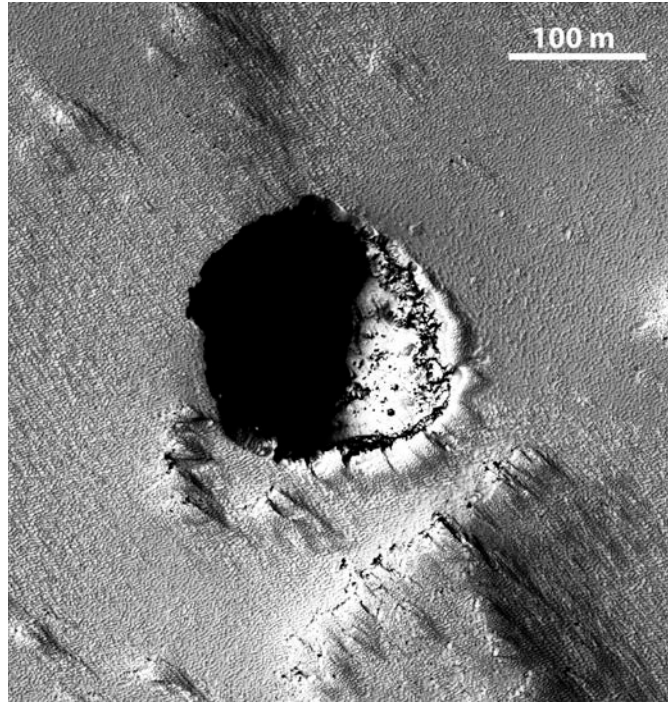


Fig. 3: Pit crater on the southeastern flank of Pavonis Mons volcano, Mars. The pit is ~180 m in diameter, and is surrounded by small dunes. Note the lack of evidence for flows coming out of the pit. Also visible is the layering in the pit wall, suggesting that the host material is a series of lava flows. Part of HiRISE image ESP_019351_1795, located at 0.457°S, 248.571°E.

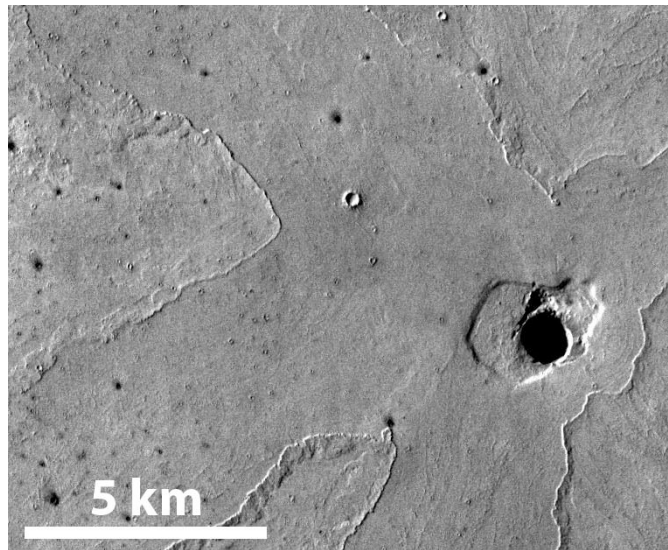


Fig. 4: This deep pit crater most likely served as the vent for a series of fluid flows on Mars that radiated from this center. It is a rare example of a Martian pit acting as the vent for a surface flow. Located at 4.6°N, 158.8°E. THEMIS VIS frame V130038008.

With the advent of high resolution images for the Moon from the SELENE (Hayuyama *et al.*, 2009) and Lunar Reconnaissance Orbiter (Ashley *et al.*, 2011) spacecraft, several examples of pits are identified in the lunar maria. Overhangs in some of these pits (Fig.5) strongly suggest that the voids continue beyond the surface depression and hint at the idea that the pits formed over lava tubes that may still be partially intact.

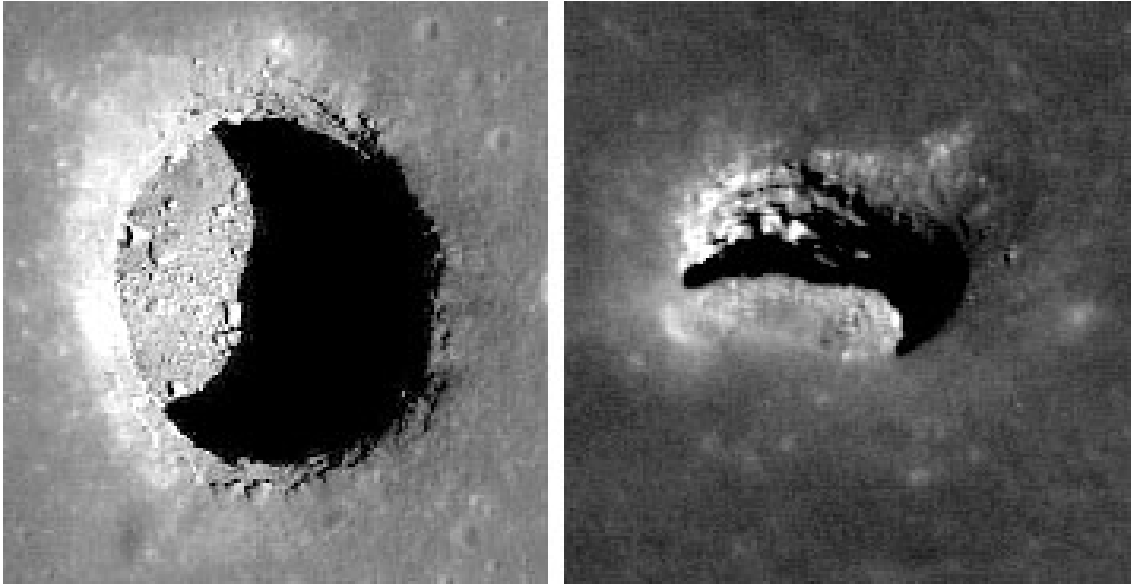


Fig. 5: Left: Pit crater ~100 m in width within Mare Tranquillitatis on the Moon. LROC narrow angle image M126710873R. Right: Oblique LROC NAC view of a pit within the Marius Hills on the Moon, clearly showing an overhang of the surface layers. This strongly suggests that the void continues beyond the crater rim. The pit is ~65 m in diameter. Image M137929856R.

Volcanoes on Venus also demonstrate clear examples of pit crater chains, consistent with the idea that they are the surface expressions of dike systems within the volcanic edifice; for example, there are a large number of elongate pits ~1 – 4 km in size on the flanks of Maat Mons volcano (Fig. 6). This arrangement is consistent with the idea that there was an episodic supply of magma from the mantle (Wilson *et al.*, 2001), with each new batch of magma progressively forming a rift zone down the flank of the volcano. Potentially, the hollows in many young impact craters on Mercury (Gillis-Davis *et al.*, 2009; Thomas *et al.*, 2014) have a similar volcanic origin (Fig. 7). Interestingly, no pit craters have, to date, been identified on Io, the volcanically-active moon of Jupiter. This may simply be an artifact of the available spatial resolution of the image data sets, or there may be a more fundamental explanation: crustal rocks on Io may inhibit the Okubo and Martel (1998) model, or the volcanoes on Io may not possess rift zones that allow the subsurface transport of magma.

Along with the (inferred) associated lava tube, planetary pit craters and skylights have attracted significant attention from the human exploration perspective. Hertz (1985) first identified lava tubes as potential shelters for astronauts on the surface of the Moon should they need to avoid radiation hazards while outside their spacecraft.

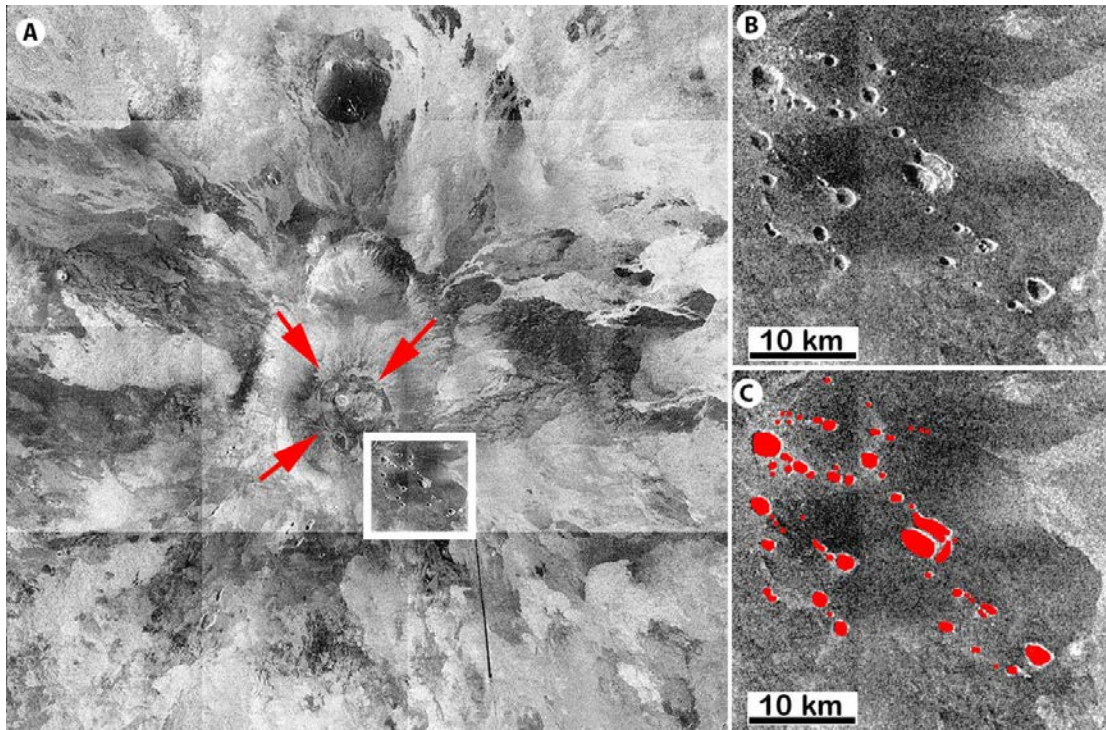


Fig. 6: Examples of pit craters on the flanks of Maat Mons volcano, Venus. The red arrows in part A define the summit caldera, and the insert marks the location of parts B and C. Part B shows the pit craters (radar look-direction is towards the right), and Part C identifies these pits in red. All images are radar images collected by the Magellan spacecraft.

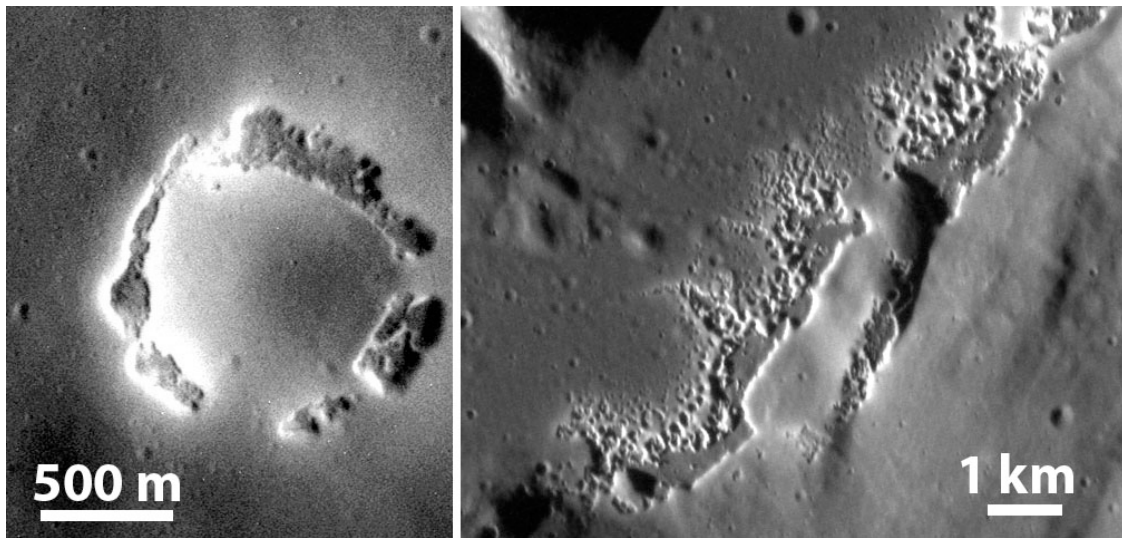


Fig. 7: High resolution view of hollows on Mercury. Left: MESSENGER NAC image 638318, Lat. 48.7°N , 134.1°E . Right: Image 2758246, Lat. 50.63°N , 320.6°E .

How to see examples in Hawaii:

There are some great examples of pit craters along the East Rift Zone of Kilauea. These can be reached from the town of Hilo by driving along Highway 11 to Volcano National Park (Fig. 8). Enter the National Park and head for Chain of Craters Road. The first pit craters that you will encounter Lua Manu and Puhimau Craters before reaching Kokoolau Crater. These are the only pit craters on the upper East Rift Zone that have not been the sites of eruptions in historic times. Then one encounters Devil's Throat, Heake Crater and Pauahi Crater. Mauna Ulu is the next crater, but prior to the formation of this lava shield between 1969 to 1974, one would have encountered Aloi Crater. These craters range in diameter from ~40 m to ~650 m in maximum width.

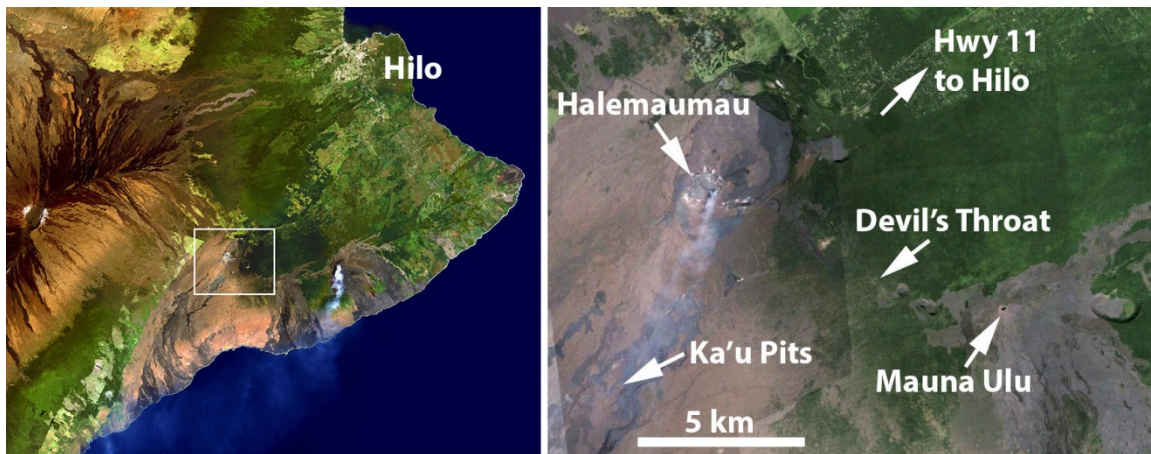


Fig. 8: Left: Overview of Kilauea volcano. White box indicates area of detail shown at right. Location of Devil's throat and the Ka'u Desert pits. Note that there is a series of pit craters that extend from Halemaumau crater to Mauna Ulu that are easy to visit.

Regardless of the size of these pit craters, the walls of many craters in Hawaii, and specifically Devil's Throat are cracked, unstable, and ready to fall in. If you visit any of them, PLEASE BE VERY CAREFUL HERE!!! Particularly if you feel an earthquake while near the rim, run away FAST! Devil's Throat is located along the East Rift Zone (Fig. 1), but if you would prefer to visit other pit craters that show clear signs of sub-surface connection, you may wish to visit two located in the Ka'u Desert (Fig. 9).



Fig. 9: Air photo of two pit craters located within the Ka'u Desert, Southwest Rift Zone of Kilauea, Hawaii. Each pit is ~45 m in diameter. Although access to this part of the volcano is currently closed due to the fume from Halemaumau crater, when roads reopen these pits are easily accessed via the southern entry to the Desert. The young flow that extends from bottom left to top right is part of the December 1974 lava flow.

References

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