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MUD VOLCANOES ON MARS?

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Mud volcanoes are common and widespread on Earth, but their possible presence on Mars has not been previously considered. The term "mud volcano" is applied to a variety of landforms having in common a formation by extrusion of mud from beneath the ground. Although mud is the principal solid material that issues from a mud volcano, there are many examples where clasts up to boulder size are found, sometimes thrown high into the air during an eruption.

Most spectacular are the Fuji-like mud volcanoes, showing a high degree of symmetry around the crater and steep (30 to 40°), concave-up slopes (Snead, 1964). The Chandragup mud volcano in Pakistan, Figure 1, has this classic form as it rises some 100 m above a level plane, with the base and crater diameters respectively being some 200 m and 30 m. This is one of a number of mud cones in Pakistan, impressive in their sizes and in the fact that they are well preserved due to the arid climate.

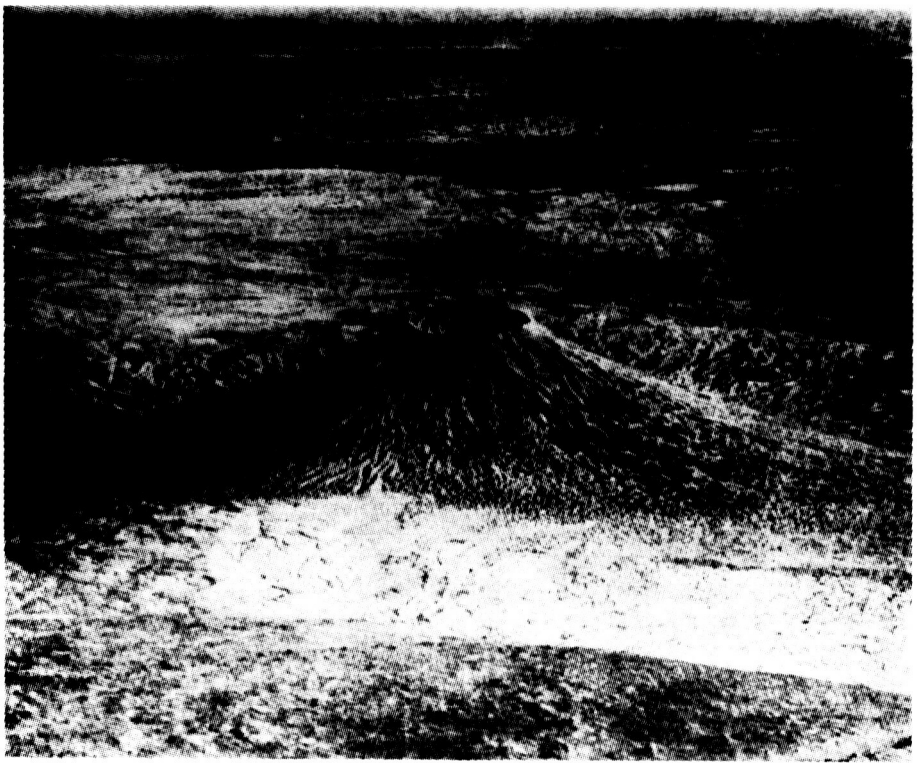

Figure 1: The Chandragup mud volcano in Pakistan.

When the Pakistan mud volcanoes are active, the craters become filled with black, watery mud (Snead, 1964). During a quiet eruption, the crater mud heaves up with the formation of large bubbles, and overflows the crater at a low point. The mud flows are composed mainly of clays and sand, but include large blocks of serpentinized ultrabasic rocks. As the mud flows slowly downslope, the side of the cone is built up and becomes a

barrier to later flows. Subsequent flows therefore cross other parts of the crater rim, and in this way a perfectly shaped cone is constructed. Explosive eruptions are rare in the Pakistan mud volcanoes. When they do occur, they are similar to the eruption of a geyser, "with rumbling noises and much agitation in the crater of the mud vent" (Snead, p. 556). In other locations the eruption of mud volcanoes has been observed to be highly explosive. Violent eruptions in New Zealand have been reported to throw mud and rocks about 100 m into the air (Ridd, 1970). Boulders weighing up to 60 pounds (27 kg) were found to have been thrown more than 100 m from one vent, and in another case a 2.5 m boulder was ejected. On Trinidad, the Devil's Woodyard mud volcano has had a history of explosive eruptions. Higgins and Saunders (1974) reported a "violent explosion heard for some miles...surface broken up and completely altered. Some of the adjacent trees had disappeared, others were thrown down." A 1909 eruption formed a crater 90 m in diameter and threw mud higher than the surrounding trees. A mud volcano on the island of Sakhlin north of Japan exploded in 1959, causing mud to cover an area of approximately 60,000 m^2 with a volume estimated at 150,000 to 200,000 m^3 (Gorkun and Siryk, 1968).

Eruptions, particularly of the explosive type, are generally accompanied by emissions of large quantities of methane. In some cases the methane is in sufficient quantity that the eruption ignites naturally and burns for several days. Sokolov et al. (1969) describe eruptions in the Soviet Union with flames rising 100 to 200 m into the air.

Snead (1964) also has reported on mud ridges in Pakistan, in the same areas where the cones are found. Mud ridges appear to have no direct connection with central vents or with definite points of eruption, but instead occur as high, broad hills with steep sides. The largest are about 600 m high, and have lengths more than 30 km. The sides of the ridges are steeper than the cones, ranging from 40 to 70°. Some ridges appear to have originated from the wholesale upwelling of viscous mud along fault zones. Others formed by the coalescence of chains of cones; one such chain formed a ridge 400 m high and yielded an enormous quantity of mud from the closely grouped vents – a single mudflow was observed to extend for more than 3 km from its vent.

Another form of active mud volcanism creates an edifice consisting of hundreds of small individual craters. In reference to such features in Trinidad, Higgins and Saunders (1974) have adopted the name *tassik*; this is a native term which refers to a circular opening in the forest without vegetation cover due to the active formation of mud volcanoes. On one tassik Higgins and Saunders counted nearly 100 separate eruptive centers. The overall edifice can be large; a number of examples in Trinidad have diameters greater than 1 km, and two elliptical examples have dimensions 2.5 by 0.8 km and 2.2 by 1.0 km.

Comparable landforms are observed on the surface of Mars in Viking orbiter images. In particular, subkilometer cones having central craters, occurring randomly in groups and sometimes in chains, could be Martian analogs to terrestrial mud volcanoes. These generally have been interpreted as small cinder cones or as pseudocraters generated by lava flows coming in contact with water (Wood, 1979; Frey et al., 1979; Frey and Jarosewich, 1982). However, a volcanic-like cone may not be what it seems, and may not even establish the occurrence of igneous volcanic activity.

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