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The role of volcano-water interactions in shaping the surface of Mars.

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HRSC Mars Express images of Ascraeus Mons and other large Martian volcanoes have been examined, but as yet no unequivocal lava-producing flank vents have been found in the upper flanks of the volcano, nor any pyroclas-tic cones. Long and voluminous flows (in excess of 300 km long and 10 km wide) radiate from the summit, but their origins are obscured within the caldera collapse in each case. A common feature are the late stage collapse pits and sinuous rilles have developed near the foot of the outer slopes, that cut across and therefore post-date all visible lava flows. Some of these sinuous rilles merge seamlessly with apparent graben, and sometimes appear to show non-gravitational flow, cross-cutting other sinuous rilles. In other cases, sinuous rilles emerge from one rimless pit and disappear into another, suggesting that they cannot have been formed by eroding lavas. We conclude that these paradoxical features are most likely to have been eroded by a volatile substance which then evaporated or sublimed away, almost certainly water. Some features can only be explained if the flow of water is at different levels below the surface, and that complete or partial collapse has taken place at a later stage. Another noticeable feature is that near the foot of the flanks, concentric graben have developed at Ascraeus Mons, Arsia Mons, and Albor Tholus. Tall volcanic constructs induce their own internal stress fields, and if there is a ductile layer within the substratum, outward spreading normally occurs, with radial leaf graben around the summit and compression at the base, the opposite of what is observed here. However, if the ductile layer is thick enough, or extremely weak com-

pared to the edifice, compression is induced in the cone and extension can occur at the base. In addition, recent analogue models show that if two ductile layers are involved, sinking of the edifice takes place, which creates summit compression, but basal compression is also present. This creates folding that is most often evidenced by normal faulting over anticlinal crests at the foot of the edifice. It is also possible to have an outer rim of extensional fractures due to flexure, and an inner ring of fold-related fractures at the base of the edifice. An example of this is the Antarctic Peninsula volcano Mount Haddington (James Ross Island). This englacial volcano has sunk into thick ice-bound sediments that are a simple analogue to the Mar-tian surface. The form of the volcano is also similar to some Martian edifices, in that it is surrounded by a scarp and debris avalanches. The central part of the volcano has a caldera and no obvious gravitational deformation is ob-served. The periphery is dominated by major thrusts with large scale fluid transfer, that often translate into major landslides and avalanches. The thrusts represent the outward extrusion of ductile rock from under the volcano. The fluid (as seen in large scale calcite veining and fluidised layers within the fault zones), represents water extrusion as the volcanic pile squeezed and heated the substrata. The structures at Mt. Haddington, and accompanying analogue models indicate that the entire edifice was subjected to a radial horizontal maximum principal stress and a minimum vertical principal stress. The principal stresses, and coulomb stresses are highest at the deforming edge of the edi-fice. This stress state is valid for the one and the two layer case, but only for the one layer case if the substrata vis-cosity is very low with respect to the edifice bulk strength. We propose that such deformation and fluid transport has also happened in the case of some of the giant Martian volcanoes. An ice-saturated regolith would be a ductile layer that would become heated and compressed under the weight of 10-22 km of lavas. Flexure of the edifice would create tensile stresses near the base, and around the edges of the flanks, where tensile cracks and graben will develop at a late stage. Alternatively, if there are two ductile lay-ers, the edifice centre is still compressed but the graben at the base is related to the basal fold. Melting of the ice beneath the volcano would create pressurised liquid water whose path of least resistance would be in the lower parts of the volcanic pile or beneath it, but would reach the surface in and around the concentric graben low on the flanks.