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The volcanotectonic structures of Ascraeus Mons

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Ascraeus Mons is the tallest of three large volcanoes situated to the NE of the Tharsis Rise and aligned parallel to a NE-SW regional structural trend. With a vertical relief of 14.9 km and an E-W diameter of 400 km, the main shield has a convex-upward morphology and a summit plateau, whilst significantly younger lava rift aprons issue from expansive embayments on its lower flanks onto the surrounding plains. The volcano hosts several types of well-preserved surface structures, and so has served as a basis for understanding Martian volcano geodynamics. Previous studies have not incorporated the full set of structures on Ascraeus Mons, however, and have been limited by photogeological data of lower resolution than that available today. We have used a GIS of MOLA, HRSC, and CTX data to map the spatial and temporal distributions of the most pronounced structures on Ascraeus Mons — its summit calderas, flank terraces, arcuate graben, and pit craters — to develop as comprehensive an evolutionary sequence for this volcano as possible. We summarise our mapping results here.

· The 55-km wide caldera complex consists of at least three NE-SW-aligned depressions, with a possible fourth caldera on the periphery. Depths range from 818 m for the shallowest caldera to 3,110 m for the deepest. Whilst most lavas on the volcano are summit-derived, even the latest flows are cut by post-caldera formation subsidence and fracturing.
· Flank terraces, topographically subtle outward-verging, convex-upward structures, encircle Ascraeus Mons in an imbricate, fish-scale pattern. 142 terraces in total extend from immediately below the summit to the basal plains, but do not occur on the rift aprons. The mean circumferential length for terraces is 31.9 km, though terraces over 60 km long lie on the NW and SE flanks.
· Arcuate graben crosscut the NW flanks and surrounding plains, and extend for ca. 90° concentric to the volcano. These structures vary in width from 400 m to 1,200 m, and are between 10 and 100 m deep. They are shallower and more laterally continuous than the pit troughs observed elsewhere on the flanks (described below), although pits do occur nearby, and in places are laterally contiguous with graben.
· Pit craters are circular or ovoid rimless depressions, between 190 and 3,000 m in diameter and several 100s m deep, that are superposed upon the latest lavas on the volcano. Rows of pits form crater chains, whilst chains can merge to form troughs. We mapped 4,166 pits across the volcano, trending circumferential near the summit to radial low on the NE and SW flanks; here, chains and troughs coalesce to form the embayments.

Caldera formation is likely the result of evacuation of an underlying magma chamber. Recent work indicates that flank terraces are compressive structures, formed by upper flank shortening of a volcano as it flexes the supporting lithosphere; flexure could also account for the arcuate graben concentric to the shield. In contrast, pit craters are probably extensional structures, formed by collapse into subsurface voids. A developmental sequence for Ascraeus Mons, therefore, needs to account for the disparate formation mechanisms proposed for these spatially coincident structures. Incorporating our findings with earlier studies of this volcano, we conclude that Ascraeus has experienced a history of rapid shield building, coeval with magma chamber evacuation, which initiated sustained lithospheric flexure and led to the formation of flank terraces and concentric graben. Main shield construction was followed by a period of repose before rift apron volcanism initiated on the lower flanks along the NE-SW regional lineament. Ultimately, the dominant tectonic regime upon the volcano's flanks changed from compressional to extensional, resulting in the development of pit craters. This model may help establish a framework for understanding the volcanotectonic histories of large shields across Mars.