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Insights into volcano-related subsidence structures on Mars from experiments and 3D strain theory

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Volcano-related subsidence on Mars has various forms, two of which are the subject of this study. On a small scale, collapse calderas have commonly developed at the tops of volcanic edifices. On a larger scale, whole edifices and their underlying basements seem to have subsided via lithospheric flexure. Previous continuum-based numerical simulations of each of these processes revealed a similar pattern of surface stress states. These stress states are generally used in conjunction with Andersonian fault mechanics to predict the structures that should form at the Martian surface in response to subsidence. For calderas, a central zone of reverse faulting and a peripheral zone of normal faulting have been postulated and observed. For lithospheric flexure, the same zones were broadly predicted, but with the addition of an intermediate zone of strike-slip faulting. The prediction of the intermediate zone has been problematic, however, because associated strike-slip faults have not been observed in nature. We report results from experimental models of caldera subsidence and lithospheric flexure, both of which produce arrays of structures that broadly conform to those observed in nature. However, an intermediate zone of strike-slip faulting predicted by Andersonian theory is, as in nature, not observed. Instead, this zone mainly comprises oblique-reverse and oblique-normal faults; 'pure' strike-slip faults are rare. Overall, the structures observed in analogue simulations of both subsidence types are more compatible with those predicted by 3D strain theory of faulting, rather than Andersonian theory. Our study suggests that a fuller understanding and prediction of faulting related to volcanic subsidence on Mars and other planets should therefore be guided by 3D strain theory.