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3-dimensional geometric modeling and parameter estimation of scoria cones of the San Francisco Volcanic Field, Arizona, USA

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The almost global availability of medium- and high-resolution Digital Terrain Models (DTMs) paved the way of new approaches in volcanic geomorphology. The increasing importance of understanding of surface processes that act during the degradation of volcanic edifices also mean a demand for geometric modeling of their surface, in order to derive parameters from the topography that are suitable for further analysis.
Our study area, the San Francisco Volcanic Field (SFVF), is a ca. 4500 km2-large volcanic region situated around the San Francisco stratovolcano at Flagstaff, Arizona (USA) that hosts some 600 scoria and lava domes, numerous lava flows with extensive volcanic ash deposits. Because of the wide range in size and age, as well as contrasting degradation of these volcanic features, several authors have analysed them in the last decades to derive general rules of their lowering. Morphometric parameters were determined that were expected to be suitable to fulfill this requirement. In his pioneering work, Wood (1980a,b) considered 40 scoria cones, while almost two decades later Hooper and Sheridan (1998) included 237 features in their study. Their manual morphometric analyses were based on topographic maps that are time consuming, therefore their limited scope can now be extended with the availability of digital data.
In the initial phase of our project more than 300 cones were analysed using the classic approach (height of the cone, width of the cone and crater, etc.). Additionally the slope histogram were analysed in order to classify the cones into different evolutionary categories.
These analyses led to the selection of a few volcanoes, that entered in the next processing phase. Firstly the derivation of parameters in two-dimensional approach were carried out. Horizontal and vertical cross sections were extracted from the DTM, and the resulting planar curves were analysed via parameter estimation. The horizontal planar outlines were approached with circles while the vertical profiles were analysed using straight lines to define slope angles. The most regular 27 cones were analysed this way. The aim of this phase is to calculate approximate slope parameter and extent for the three-dimensional (3D) parameter estimation to prepare this rather complex step.
In the 3D estimation phase the aim is to fit a 3D geometric cone to the surface data using the aforementioned starting values. This type of parameter estimation may turn to be problematic, since the multidimensional parameter space can be very complex, therefore the applied parameter searching technique, the simplex algorithm may tend to a local minimum, avoiding a global, better fit conical shape.
A few very regular cones were selected for this purpose. The results show that in most of the cases a very good fit is achievable if the initial simplex is carefully selected. In this case, the residuals often remain below +/-20 m. If the volcano is less regular, or there is a break in the slope angle at the lower elevation parts, the fit is not so successful, giving residuals reaching 50 m.

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