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DEM-based Computation of Dissection Index and Depth of Stratovolcanoes in Relation to Formation Age

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Erosional changes of volcanic edifices are related to natural hazards such as landslides and debris flows. Therefore, understanding erosional changes of volcanoes is an important issue in both earth science and disaster prevention, although this issue remains to be fully investigated. Most previous studies on volcanic erosion included qualitative and subjective aspects. The purposes of this study are: 1) develop an automated method to quantify the dissection of volcanic edifices from DEMs (Digital Elevation Models) objectively using GIS and originally-coded computer programs; 2) measure the dissection index (DI) and depth (Dd) of volcanoes whose formation ages are known to explore change in DI and Dd with time; and 3) discuss environmental influences on volcanic erosion by comparing DI and Dd with environmental factors.
DI and Dd were derived from the original surface of a volcano, reconstructed by the round seek method developed by the author. The method is based on the algorithm of convex hull and provides contour lines. The obtained contours were interpolated to derive a continuous surface of the original volcano using Kriging interpolation. The surface was then compared with that reconstructed by an existing method, indicating that the new method can perform more appropriate landform reconstruction through valley filling. The method was then applied to 70 stratovolcanoes comprising 80 measurement areas in the northern parts of the circum-Pacific orogenic belts.
The dissection index (DI) is positively correlated with the formation age of the volcano with a correlation coefficient of $r = 0.586$ ($p < 0.05$). The dissection depth (Dd) and the age is also positively correlated with $r = 0.421$ ($p < 0.05$). Despite these general trends, influences of some environmental factors were detected. Volcanoes with valleys formed by glacial erosion tend to show higher Dd than those with valleys formed only by fluvial erosion, indicating that glaciers are more effective for volcanic dissection than rivers. On the other hand, there is no distinct difference in DI for glaciated and non-glaciated volcanoes. Fluvial erosion form dense and complex valleys. Therefore DI indicates horizontal complexity of a landform rather than the magnitude of erosion. Lower temperature is also associated with higher Dd, reflecting the high intensity of glacier erosion as noted above. In addition, higher volcanoes tend to have larger DI and Dd, suggesting that the distance from the base level of erosion affects the dissection of volcanoes. DI and Dd do not increase with annual precipitation. This observation may reflect the protective effect of thick vegetation, because the study areas are located in temperate mid-latitude to cold polar zones where vegetation density is high. Although a previous study indicated that the erosion rate in volcanic regions becomes similar to that in non-volcanic regions after 0.1 Ma has passed since the formation of volcanoes, the result of this study indicates that the erosion rate in volcanic regions declines much faster. The method developed in this study seems to be applicable to many other volcanoes, although the method is inappropriate for volcanoes covered by thick lava flows with well-developed microtopography, and too old volcanoes whose original surfaces have already been lost from their ridge lines.

Keywords: Volcanic topography, Dissection Index, Dissection Depth, Formation age, DEM