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Insights into subglacial eruptions based on geomorphometry: Broad scale analysis of subglacial edifices in Iceland

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The two main types of subglacial volcanic edifices, tuyas and tindars, have classicaly been known for their distinct morphometric characteristics. Tuyas are roughly equidimensional, steep-sided, flat topped mountains, while tindars are elongate, linear, steep sided, serrated ridges. In particular, the passage zone is morphometrically diagnostic, with a break in slope marking the transition from steep scree flanks to a low sloping lava cap [e.g. 1]. The passage zone thereby records the englacial water level coeval with delta formation and thereby provides important paleoenvironmental parameters regarding ice thickness, paleo-ice surface and the eruption environment.

This study utilizes these morphometric characteristics to make a broad scale assessment of Icelandic subglacial edifices in the neovolcanic zone based on the TK-50 digital elevation model (20m/pixel) from the company Loftmyndir ehf. The edifice boundaries are delimited by concave breaks in slope around their bases and the passage zones are extracted as convex breaks in slope. This extraction is performed through object-based image analysis of slope and profile curvature maps with the eCognition program [2]. The MORVOLC code [3] is then used to calculate several morphometric parameters for each edifice: volume, edifice height, passage zone height, slope, base area, base width, ellipticity and irregularity.

Analysis of the morphometric parameters allows grouping of subglacial edifices by to volume, with a continuum of landforms ranging from small tindars (group 1) to large tuyas (group 3), with an intermediate complex group of edifices (group 2). The plan shape indexes (ellipticity and irregularity) and the strike of main elongation show a first order correlation with the 3 classes and groups. Furthermore, correlations of passage zone heights, volumes and information regarding englacial lake stability allows us to investigate several aspects of tuya formation, including(1) spatial distribution of tuya sizes in rift and plume dominated volcanic systems, (2) estimation of paleo-ice surface height based on passage zone elevation, and (3) correlation between eruption size, approximate paleo-ice surface height and meltwater drainage.
This study shows how a new semi-automated geomorphometric analysis of subglacial volcanic morphologies can provide information on the eruption environment. Furthermore, the technique can be used for submarine and planetary volcanic environments given a sufficiently accurate topographic model, providing a consistent approach to compare volcanic edifices in different environments.

[1] Jones (1969) Quarterly Journal of the Geological Society 124, 197-211. [2] Benz et al. (2004) ISPRS Journal of photogrammetry & remote sensing 58, 239-258. [3] Grosse et al. (2012) Geomorphology 136, 114-131.