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Volcano regrowth after sector collapse: Insights from aerial and satellite photogrammetric data at three volcanoes in Kamchatka

Alina Shevchenko (1,2), Viktor Dvigalo (2), Thomas R. Walter (1), René Mania (1), and Ilya Svirid (2)

(1) GFZ German Research Centre for Geosciences, Potsdam, Germany (alinash@gfz-potsdam.de), (2) Institute of Volcanology and Seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia (dvig@kscnet.ru)

Tall volcanic edifices are subject to gravitational instability and destruction. However, after sector collapse and large-scale destruction many volcanoes begin to regrow, gradually refilling the escarpment. Often, this process begins with the formation of lava domes in newly formed collapse scars. In the case of continued activity and the predominance of constructional over destructive processes, the collapsed volcanic edifice may develop into a conical morphology. However, details on regrowth from dome- to cone-building volcanoes have been suspected but barely investigated. Here, we present a comprehensive analysis of morphologic observations of edifice regrowth at Shiveluch, Bezymianny, and Avachinsky volcanoes in Kamchatka, Russia. We applied photogrammetric processing of aerial images obtained since 1967, and compare to the current tri-stereo Pléiades satellite images from 2017 and 2018. The processing was performed in the Erdas Imagine 2015 and Photomod 5 software, yielding a time series of three-dimensional point clouds for each of the volcanoes. Using these datasets we investigate morphologic, structural, and volcano-tectonic changes of the three studied edifices. We also derived volumes of eruptive material by calculating differences between consecutive point clouds. Thus, our detailed photogrammetric analysis enabled to identify different stages and locations of volcanic regrowth after sector collapse. We find that the regrowth of the conical edifice in the sector collapse escarpment develops in a systematic way, from initial endogenous to exogenous lava dome formation. We suggest a continuum model explaining the transition in volcanic regrowth and discuss possible mechanisms for it.