Geophysical Research Abstracts
Vol. 20, EGU2018-11090-1, 2018
EGU General Assembly 2018

Origins and implications of mixed avalanche deposits from the 3 March 2015 eruption of Villarrica volcano, Chile

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After showing signs of increasing vigor in February 2015, on the morning of 3 March 2015 Villarrica volcano produced a short-lived (∼30 min) eruption characterized by a lava fountain that ejected clasts up to 1.5 km above its summit. While short-lived, the interactions between tephra and summit snow and ice produced small lahars in four different valleys on the north and east sides of the volcano. The tephra-snow/ice interactions produced 'mixed avalanches', which could be seen periodically as glowing avalanches with steam plumes moving down the summit flank at velocities estimated from video analysis to be 10.3-24.4 m/s (37-88 km/hr). The deposits have been mapped in the field and with remote sensing, and their morphologies were documented using a UAS to produce a 3-D point cloud two days after the eruption. Subsequent work has included field description and sampling of five deposits (a minimum of 19 different lobes were distinguished via remote sensing), granulometry, SEM textural analysis, and EDS compositional estimates of glass compositions (basaltic andesite). Field measurements show that locally the avalanches were erosive and produced grooves in ice surfaces up to almost 2 m in depth and with maximum widths of almost 5 m. But at the distal ends of the deposits apparent ridges of ice up to 2 m in height were formed, with only a modest (∼0.3 m) thickness of tephra cover. While average deposit grain sizes are in the fine-lapilli to very coarse-ash range (-2 to 0 phi), juvenile clasts up to 0.5 m cubed in volume were found near the distal end of the longest flow (over 3 km from the summit). The total summit area covered by avalanche deposits is estimated to be 1.8 square km with a volume of approximately 540,000 cubic m, assuming average deposit thicknesses of 0.3 m. One dimensional thermal modelling of the average tephra sizes shows that if they were deposited as air fall from greater than 500 m above the vent, they would have cooled almost to ambient conditions before landing on the ice surface. As we know that the avalanches melted enough snow and ice to produce small lahars, we suggest a model where much of the initial avalanche material is coarser (coarse lapilli to block/bomb) than the final tephra deposits. The larger clasts would have conserved most of their thermal energy during air fall even from the maximum observed column height (1.5 km), and could then release that conserved energy during transport down the summit slopes. Additionally, mixing of the large clasts with eroded ice fragments would have facilitated melting. Much of the tephra, regardless of size, has glassy margins and locally bomb-sized clasts have polygonal fractures. These textures are also consistent with heat transfer in a coolant-enhanced (e.g. water-rich) environment. Reviews of images from previous eruptions show that this type of mixed avalanche deposit is probably a common phenomenon at Villarrica and potentially at other mafic, glacierized volcanoes.