Journal of Volcanology and Geothermal Research 431 (2022) 107668

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.journals.elsevier.com/journal-of-volcanology-and-geothermal-research

Collisional interactions and the transition between lava dome sector collapse and pyroclastic density currents at Tutupaca volcano (Southern Peru)

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ARTICLE INFO

Keywords:
Volcanic debris-avalanche deposit
Local kinematics
Block clusters
Striations
Sedimentology

ABSTRACT

We describe sedimentological variations of the block-rich debris avalanche deposits and associated pyroclastic density current deposits emplaced around 1802 CE from Tutupaca volcano in southern Peru. We use these exceptionally well-preserved features to document the collisional shearing contact between the avalanche and coeval pyroclastic density currents. Furthermore, we show how the first stages of the edifice collapse and *syn*-cataclastic emplacement process affect the block-size distributions.

With field observations, we describe imbricated block clusters, jigsaw cracks and striations related to elongated ridge structures on the deposit surface. Sedimentological and statistical methods (Fourier Shape analysis and Shape Preferred Orientation measured on 208 blocks and 566 mesoscale structures) help us to characterize the cataclastic gradient and establish the collisional relationships between different units. We determine that the proximal impacted deposits and block lithofacies from ridges may be related to distal block units around ~10 km run-out distance. Different block clusters indicate a kinematic transition between avalanche units to pyroclastic density currents. Block shape parameters help to differentiate rounded blocks resulting from matrix abrasion with and striated blocks from ridges related to proximal imbricated block clusters. From the statistical dataset, a few equations have been developed indicating a common cataclastic origin with a co-genetic evolution of block lithofacies during sequential *syn*-cataclastic emplacement.

The dome collapse is associated with a specific granular flow regime between avalanche and pyroclastic density currents with secondary reworking. Cyclic impact waves contribute to block cluster growth. Clusters are disaggregated during shock propagation. The inherited shapes of the block lithofacies with $a/b = 1.2$–2 and ellipse = 0.2–2.5 indicate the reworking by impact waves. A multidirectional switch to mass spreading in the median zone between 2 and 6 km may be considered with secondary flow and segregation waves. A basal frictional regime with striations is differentiated from collisional cataclastic flow, generating polymodal grooves during peak velocity at the flow front. Impact forces around $\sim 15.7 \times 10^{10}$ N are implied by suggested clast velocities around 8.86 $m.s^{-1}$ and the transitional regime between avalanche units and pyroclastic density currents between 15.5 and 39.6 $m.s^{-1}$. An extensional disaggregation with the fractal dimensions (D) of the surrounded matrix between 0.6 and 2.8 characterizes the granular transport. A collisional shearing contact probably operated between avalanche units and pyroclastic density currents, which contribute to co-genetic evolution of block clusters from median to frontal distal zones. In the distal zone, abraded block clusters and tilted blocks are related to frontal reworking by impact wave.

The cataclastic gradient of avalanche units is correlated with the pyroclastic flow regime. Semi-quantitative analysis of block clusters provides information about *syn*-emplacement processes during sequential impact waves related to volcanic debris-avalanche units and pyroclastic density currents.

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https://doi.org/10.1016/j.jvolgeores.2022.107668
Received 5 December 2021; Received in revised form 20 August 2022; Accepted 1 September 2022
Available online 9 September 2022