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PII: S0377-0273(17)30748-5
DOI: doi:10.1016/j.jvolgeores.2018.03.003
Reference: VOLGEO 6321

To appear in: *Journal of Volcanology and Geothermal Research*

Received date: 21 December 2017
Revised date: 26 February 2018
Accepted date: 1 March 2018

Please cite this article as: Philippe Lesage, Michael J. Heap, Alexandra Kushnir , A generic model for the shallow velocity structure of volcanoes. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Volgeo(2017), doi:10.1016/j.jvolgeores.2018.03.003

A generic model for the shallow velocity structure of volcanoes

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Abstract

The knowledge of the structure of volcanoes and of the physical properties of volcanic rocks is of paramount importance to the understanding of volcanic processes and the interpretation of monitoring observations. However, the determination of these structures by geophysical methods suffers limitations including a lack of resolution and poor precision. Laboratory experiments provide complementary information on the physical properties of volcanic materials and their behavior as a function of several parameters including pressure and temperature. Nevertheless combined studies and comparisons of field-based geophysical and laboratory-based physical approaches remain scant in the literature. Here, we present a meta-analysis which compares 44 seismic velocity models of the shallow structure of eleven volcanoes, laboratory velocity measurements on about one hundred rock samples from five volcanoes, and seismic well-logs from deep boreholes at two volcanoes. The comparison of these measurements confirms the strong variability of P- and S-wave velocities, which reflects the diversity of volcanic materials. The values obtained from laboratory experiments are systematically larger than those provided by seismic models. This discrepancy mainly results from scaling problems due to the difference between the sampled volumes. The averages of the seismic models are characterized by very low velocities at the surface and a strong velocity increase at shallow depth. By adjusting analytical functions to these averages, we define a generic model that can describe the variations in P- and S-wave velocities in the first 500 m of andesitic and basaltic volcanoes. This model can be used for volcanoes where no structural information is available. The model can also account for site time correction in hypocenter determination as well as for site and path effects that are commonly observed in volcanic structures.