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Dropping sand bags from helicopters: A low cost and environmentally benign approach to determine subsurface velocity and attenuation structure of active volcanic systems

AD Jolly (1), L Chardot (1,2), S Sherburn (1), J Cole-Baker (1), BJ Scott (1), N Fournier (1), and JN Neuberg (3)

(1) GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo, New Zealand(a.jolly@gns.cri.nz), (2) Dept. of Geological Sciences,University of Canterbury, Christchurch, New Zealand, (3) School of Earth and Environment, The University of Leeds, Leeds, UK

Obtaining estimates of the seismic velocity and attenuation structure of volcanic systems is considered valuable from a monitoring perspective but can be extremely costly and time consuming due to the potential environmental impacts, safety issues and the permitting process. Here, we present an easy, low cost and environmentally benign alternative whereby the shallow velocity and attenuation structure can be obtained via high impact sandbag drops from helicopter. We conducted such a sandbag drop experiment at White Island volcano on 23 September 2011, during the final stage of a 6 month deployment of 14 broadband seismometers. Three drops were attempted, two at either end of a 5 station linear array within the crater floor, and the third within the volcano's shallow active acid crater lake. The bags were dropped from $\sim$400 m height and contained $\sim$700 kg of fine beach sand held within nylon sacks having a volume capacity of $\sim$2.0 m^3. The impact velocity was estimated at $\sim$70 m/s yielding a kinetic energy of about 10^6 to 10^7 Nm. The source position was established by GPS on the resulting impact crater and was accurate to within $\sim$5 m. The lake drop position was estimated from video footage relative to known ground features and was accurate to $\sim$30 m. Impact timing was achieved by drop placement close to, but not on, the nearby seismometer recording systems. For the crater floor drops the timing was constrained to within $\sim$0.05 s based on distance from the closest stations.

The low kinetic energy and strong attenuation of the crater floor meant that strong first-P arrival times were limited to an area within $\sim$1 km of the impact position. We obtained a rough velocity estimate of about 1.0-1.5 km/s for the unconsolidated crater floor and a velocity of $\sim$1.5-2.0 km/s for rays traversing mostly through the consolidated rocks comprising the crater walls. Attenuation was found to be generally very strong ($Q < 10$) for both consolidated and unconsolidated parts of the volcano.

Results show that low-cost sand bag drops can be viably used to determine shallow near surface velocity and attenuation structure in volcanic environments where use of other active source methods may be problematic due to environmental, permitting or cost issues.