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Wave properties of explosion earthquake and precursory tilt change associated with vulcanian eruptions at Lokon volcano

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Lokon-Empung is one of the most active volcanoes in Indonesia. It is a twin volcano located in the north arm of Sulawesi Island. The volcano began eruptive activity at Tompaluan crater, which is on the ridge connecting Lokon and Empung peaks, in the year of 1829 after several hundred years of quiescence. Vulcanian eruption activity is considerably high, so we began temporal seismic and tilt observation at Lokon-Empung volcano since September 2012 to understand the mechanism of the vulcanian explosion and its preparatory process. Here we report wave properties of explosion earthquakes and precursory tilt changes as a preliminary step toward the source mechanism analysis.

Four broadband seismometers (Trillium 40) are deployed around the Lokon-Empung volcano in the distance range of 1.6 - 6.8 km from the Tompaluan crater. A high-sensitive tilt meter (Pinnacle Denali) is also installed at the closest station WAILAN which is connected by a wireless network to Kakaskasen Volcano Observatory (KKVO) in Tomohon City. Each seismometer is connected to a data logger (HKS-9550) to record seismic data in a CF card with an A/D resolution of 24 bit and a sampling rate of 100 Hz with time stamps of GPS clock. Tilt data digitized every one second within the tilt meter are transmitted to a laptop PC at KKVO once per day. Seismic data of WAILAN is sent to Japan as win format packet through the wireless network and global internet on a trial basis.

An explosion earthquake on September 28 was relatively small, but recorded at all four seismic stations. Polarity of P waves show compression at all stations. Seismogram of the station TINOOR, about 2.6 km northeast of the crater, has the largest amplitude among four stations and shows monochromatic waveform different from those of the other stations. Since a tectonic earthquake shows similar waveform and a noise spectrum has a dominant peak around 2 - 4 Hz corresponding to the monochromatic waveform, it is recognized as the special site effect at TINOOR. Explosions on October 5 and November 11 had obvious onset and short duration within about 1 minute. Among the analyzed events, the explosion earthquake on October 5 has the largest amplitude in the order of 0.001 m/s at the station WAILAN. The visual report on the height of ash column is about 1500 m above the crater. Before the October 5 eruption, small inflation phase around crater area can be seen in tilt record. The amount of tilt change is about 80 nanoradian. Duration of the inflation phase is about 40 minutes, which is almost same order to those found in Semeru volcano (3˜30 minutes). Polarities of P wave of October 5 and November 11 explosions are both compression as with the explosion on September 28. Although the seismograms of these three explosions seem different each other in original non-filtered traces, we can find very similar waveforms in the lower frequency band below around 1 Hz. This similarity indicates that the explosion mechanisms of these events have common physical process. In the low-pass filtered seismogram, large dilatational phase is identified after the compressional P wave and then clear retrograde motion representing Rayleigh wave appears. These waveform characteristics are similar to the explosion earthquakes at Sakurajima, Suwanosejima that often explode with Vulcanian eruptions. While, small deflation phases appearing about a few seconds before the initial compression phase that are reported for the explosion of Suwanosejima and Semeru volcanoes are not well recognized.

Keywords: Vulcanian eruption, explosion earthquake, tilt change