A large-scale block slide over a buried old caldera triggered by the 2011 March 11 M9 earthquake Japan: A case study for understanding of earthquake triggering mechanism of volcano flank collapse

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A flank collapse of a volcano is a rare but extremely devastating hazard that may claim many lives as well as huge sociological and economic damage. Despite keen demand for revelation of the mechanisms for the development of effective mitigation measures, the rareness of the events prevents accumulation of basic data for a detailed analysis. The unique exception of a scientific surveillance opportunity on such mass movement was the 1980 Mt. St. Helens flank collapse which were closely monitored and observed by scientists using the most advanced measurement instruments up to the date. The collapse is believed to be triggered by an M5+ earthquake but the detailed mechanism of the initiation of the sliding remains as a mystery (Voight, 1981). One possible remedy to resolve the lack of essential data is to learn from of similar geodynamic events having common driving mechanism. An example of such events is a large scale block sliding triggered by a big earthquake. The March 11, 2011 earthquake cast strong ground shaking over a large part of the northeastern Japan. A space borne L-band radar interferometry (ALOS/PALSAR) revealed a wide distribution of ground surface instability. Among those a large horizontal block slide found over a buried late Cenozoic caldera (Hanayama caldera; Yoshida et al., 2005) about 50km to the north of Sendai city deserves close attention for a detailed analysis. An interferogram spanning over the quake depicted a clear fringe pattern indicating a horizontal sliding of ground block of 7km size. The estimated slipping distance was larger than several decimeters toward east. Another data revealed that the same block slipped during 2008 Iwate Miyagi Inland earthquake (M7). This repeating tendency suggests the vulnerability prone to the strong ground shaking inherent in a structural background. Strong motion record at a nearby seismic station registered the maximum vertical acceleration as large as 1.9G. The horizontal components were almost of the same order. A permanent displacement derived from the double integration of the acceleration was as large as 4m in EW direction showing a good agreement with GPS results. We assumed that the sliding was initiated when the Amontons-Coulomb friction criterion is exceeded. A simple calculation using the strong motion record showed that during the most turbulent period the shear force driven by the horizontal seismic motion became larger than the friction force. It is conceivable the sliding was initiated the friction status changed from static to kinetic. A large spatial wavelength of the seismic wave is likely to make the coherent triggering of a 7km size block possible. We also infer that boundary between old caldera basement and the overlying pyroclasts of later volcanism acted as a sliding surface. This example demonstrates a possibility that a flank failure may be triggered by an analogous mechanism on a volcano flank, if a geological setting is similar.