Vertical displacement in Naruko Volcano area after the 2011 Tohoku earthquake deduced from precise leveling survey

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Great East Japan Earthquake occurred on 11 March 2011, causing large crustal deformation in the Tohoku region. GEONET observed subsidence exceeding 1m at Pacific coast and becoming smaller toward west (http://www.gsi.go.jp/common/000059956.pdf). To detect the vertical displacement inland, the first leveling survey was conducted in Naruko area, Miyagi prefecture, on east-west direction using a second-order leveling route along the National Route 47 for 10km in August 2011, as a part of summer field seminar by the Division of Earth and Planetary Material Science, Tohoku University. Contrary to the expectation before the survey, the subsidence increased westward in this section as compared with the leveling results in 2009 by Geospatial Information Authority of Japan (Tsukamoto et al, 2014). By In-SAR analysis, Ozawa and Fujita (2013) and Takada and Fukushima (2013) showed that Kurikoma-Naruko volcanic region subsided locally coincident with the earthquake. The westward relative subsidence detected by the leveling was in harmony with these results. The second leveling survey in August 2013 showed that further subsidence had progressed on the same route, and the displacement pattern was almost similar to that in 2011 (Tsukamoto et al, 2014).

To detect the subsequent displacement, we made the third precise leveling survey on 27-31 August 2015 on the same leveling route (benchmark number 047-064, 066, 068, 070, 072, 074 from east-west; hereafter indicated as BM64, BM66, etc.). We used bar-code leveling rods (Leica GPCL3) and an electronic digital level (Leica DNA03). We conducted round-trip survey between each benchmarks, and all residual errors fell within the acceptable range of the first-order leveling.

Relative to August 2013, BM66, BM68, BM72, and BM74 subsided 7.6 mm, 14.6 mm, 31.8 mm and 36.2 mm, respectively, against the eastern end BM64. These indicate westward-growing subsidence has continued (or probably is still continuing) along the survey route after August 2013, although the deformation rates have decelerated. The only exception is BM70; subsidence had changed into 4.6 mm uplift. This is the only uplift we have detected on this survey route since the 2011 Great Japan Earthquake.

Postseismic vertical displacements detected by GPS array, equipped semi-parallel to National Route 47 by Tohoku University, indicate that the surveyed area corresponds the transition zone from eastern uplift to western subsidence. Relative to the GPS station 0174 whose longitude is close to that of BM64, the next two western GPS stations collateral to the survey area have been subsiding, which is in harmony with our survey results. On the contrary the uplift such as seen at BM70 is undetected.

Leveling surveys in 1969 and 2009 by the Geographical Survey Institute indicate that BM70 subsided against BM68 while BM72 and 74 uplifted during this period. According to Prima and Yoshida (2010) and Ogawa et al. (2014), the eastern edge of the rim of Naruko caldera crosses between BM68 and BM70. The unique behavior of BM70 may be caused by such local geologic structure.

Keywords: Great East Japan Earthquake, Naruko caldera, precise leveling survey, subsidence

