Study of subsurface and geological structure around the Togi-gawa Nangan Fault based on integrated analysis of seismic reflection method and gravity exploration

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The Togi-gawa Nangan Fault is a 2 km fault with NW-SE strike and uplift on the south-eastern side distributed along the boundary of the mountain and plain along the Togi River, in the Miocene volcanic rock area in the western coast of Noto Peninsula, central Japan, which was reported by Active Fault Research Group (1991). Recently, Imaizumi et al. (2018) suggested that the fault is an estimated active fault of approximately 6 km in length accompanied by right-lateral offset streams. Hiramatsu et al. (2019) conducted an analysis using gravity anomaly, gravity gradient tensor, and two-dimensional Talwani's method (Talwani, 1959) around the fault and revealed that it is a reverse fault dipping 45°–60° to the southeast, and the spatial extent of the fault structure is comparable to the total length of the surface trace of the fault proposed by Imaizumi et al. (2018). In this study, we conducted a borehole and seismic reflection survey around the Togi-gawa Nangan Fault and performed an integrated analysis of the reflection and gravity data of Hiramatsu et al. (2019) to reveal the fault geometry and subsurface and geological structure around the fault.

A borehole survey of 200 m depth was conducted at approximately 50 m southeast of the geomorphologically estimated fault trace. The fault fracture zone within the andesite was penetrated from 134.5 to 135.1 m in depth. It was mainly composed of non-cohesive fine materials with clasts of 0.2–10 cm in diameter and contained a slip surface with slickenside and steeply pitching striation. Reverse fault movement was estimated by the preferred orientation of fragments and the drag of distinct colored muddy layers in the fracture zone. These features indicated that the fault fracture zone is related to the Togi-gawa Nangan Fault estimated by the geomorphic signatures.

A seismic reflection survey was conducted on a 7 km survey line across the Togi-gawa Nangan Fault zone. We deployed 276 seismometers every 25 m on the survey line, and two large vibroseis vehicles shot at every 50 m on the line. The seismic data were processed to obtain reflection seismic profiles. We applied the MDRS (multi-dip reflection surface; Aoki et al., 2010) and CWT (continuous wavelet transform) method to enhance CMP (common mid-point) reflection stacking in the volcanic rock area. The MDRS method produced continuous reflection surfaces in the shallow part and clearly delineated anticlines. The CWT method produced high-resolution reflection surfaces and discontinuities. We delineated seismic discontinuities interpreted as a seismic fault plane having a 50°–60° dip toward south, which is located in the extension of the fault observed in the borehole survey. Furthermore, we applied the refraction tomography method using the first breaks picked from refracted waves. We used the Monte Carlo reliability method for tomographic inversion, which contains randomly produced many initial models to reduce the effect of the dependency on initial models. The tomographic inversion result shows a high velocity zone in the middle of the survey line, which is located on the hanging wall block of the fault.

We calculated the Bouguer gravity anomaly by Talwani's method, using the subsurface density structure determined from the interpretation of the seismic reflection survey. Following Hiramatsu et al. (2019), the

layer densities were set as 1700 kg/m^3, 2300 kg/m^3 and 2650 kg/m^3 from the upper to lower layers, respectively. A layer of 2650 kg/m^3 was assumed to be up-heaved on the hanging wall of the 50˚–60˚ southeast dipping fault plane. As a result, the calculated Bouguer anomalies were substantially comparable with the observed anomalies.
From the results, we concluded that the Togi–gawa Nangan Fault is a steeply southeast dipping reverse fault with an up-heaved and high-density part on its hanging wall.

Keywords: Seismic reflection survey, MDRS method, Gravity survey, Two dimentional Talwani's method, Reverse fault

