Identification of active fault location using real-time ground measurements of atmospheric methane concentration by portable Cavity Ring-down Spectroscopy system: Case study at the Atera fault

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Faults and associated fracture zones often provide pathways for the migration of gases, such as methane, hydrogen and helium, formed in the deep subsurface formations. It is expected that information on fault location and fault activity may be obtained by measuring trace gas concentration at the ground surface.

Development of atmospheric trace gas measurement technology using Cavity Ring-Down Spectroscopy (CRDS) enabled us to measure methane gas concentration with an accuracy and precision of a few ppb and a dynamic range of 0 to 5000 ppm.

In order to investigate the applicability of this technology to active fault survey, we conducted field measurements of methane gas concentration using two portable CRDS gas analyzers (Manufacturer: Picarro Inc, models G4301 and G4302) at the Atera fault area in Gifu prefecture. Both instruments have capability of measuring methane concentration with accuracy of 3 ppb and a response time of less than 1 second. Field measurements were carried out at two locations, a fault outcrop at Tase and a fault cliff at Tsukechi town both in the Nakatsugawa city.

For measurement at the fault outcrop, a soil chamber, connected to the G4301 instrument was placed on the ground surface. Concentration of methane released from the fault was measured to be between 20 to 30 ppm. Methane release was confirmed only at the vicinity of the fault gouge and concentration 1m away from the gouge was found to be close to atmospheric background level, 1.85 to 1.88 ppm. Kurosawa et al. (2010, JAEA - Data / Code 2010 - 36) reported that maximum methane concentration was 168 ppm from their measurement using shallow boreholes excavated at the six locations along the outcrop of the Atera fault.

In the vicinity of the fault cliff, two CRDS instruments were mounted in a car and methane gas concentration in the atmosphere along the road was measured continuously with a car speed of several km/h to 30 km/h. Location of the measurements were also recorded using a GPS system. The measurement results showed anomalies of methane concentration at the two locations, approximately 1 km apart from each other, where the road and the extension of the cliff crosses. The peak atmospheric concentration of the anomalies were 1.95 to 2.05 ppm. The nearly 100 ppb difference between the anomaly peaks and the background is significant compared to the measurement accuracy of 3 ppb of the instrument. The anomalies were detected repeatedly at each location when we crossed the fault cliff. Furthermore, the methane concentration obtained by the two instruments were almost identical, confirming that these anomalies were the real responses and not associated with instrument noise.

The anomaly of 100 ppb from background suggests the methane gas emitted from the fault is diluted to about 1/200 to 1/1000 of source gas concentration. Such a small concentration signal was hardly detected by conventional technology and was successfully detected by using the CRDS technology we employed this time.

In summary, we have confirmed that methane is emitted at the very vicinity of the fault plane at the Atera fault. We also found that the location of the fault can be successfully detected using the CRDS instrument installed on a survey vehicle. From these results, we expect that trace gas measurement using a CRDS technology can be one of the promising approaches to delineate the locations of the active faults creating migration paths of the deep-seated fluids.

This report is part of the achievement in FY2018 by the "Research Committee on Application of High-Accuracy Trace Gas Measurement Technology to Geological Exploration (chairman: Professor Tomochika Tokunaga, the University of Tokyo)” that is operated by the Fukada Geological Institute.

Keywords: Methane, Active fault, Gas Migration, Cavity Ring-Down Spectroscopy, Exploration, Concentration Measurement