Identification of gas migration pathways around faults and fold axes using high-precision methane measurement technology

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In a rock mass, fractures in various scales often provide preferential fluid and mass transport pathways. For this reason, it is essential to characterize the geological and transport features of fractures in scientific and engineering applications, such as oil and gas production, water resources management, geothermal energy development, carbon dioxide underground storage, and geological disposal of radioactive waste. The authors have been studying a technique to identify fluid transport pathways based on the anomalies of methane concentration in the atmosphere using Cavity Ring-down Spectroscopy (CRDS) technology, which is now widely used in the field of greenhouse gas measurement.

In this study, we carried out the on-ground measurement of methane concentration, at the Horonobe town, northern Hokkaido, located in the Neogene siliceous rock formation.
The Omagari Fault runs north-south direction the Horonobe town, where a fold structure with a north-south axis has developed due to east-west crustal stress. Around the Omagari Fault, oil and gas signals have been found during the surveys conducted for the development of oil and gas fields in the Taisho era to the early Showa era, suggesting the existence of fluid migration pathways that reach the surface from underground oil and gas reservoirs. In this presentation, we report the methane seep profiles along the streams and trails crossing the Omagari fault and anticline axis.

We used a portable CRDS instrument, G4301 by Picarro Inc., that is capable of measuring methane gas concentrations with an accuracy of 3 ppb and a response time of less than 1 second. The measurement data is displayed on a tablet connected via Wi-Fi and stored on a hard disk with location information obtained from GPS.

From the total of 5 days of measurement, we found substantial methane anomalies at the three areas, Omagari anticline, Omagari fault, and the boundary of the Yuchi and Koetoi formation.

In the vicinity of the Omagari anticline axis, we found an increase in atmospheric methane concentration over a distance of about 60m with maximum values of 6.9 ppm and 31.9 ppm for measurement in two different periods. By removing the surface soil with a depth of 5 cm, we detected the methane concentration as high as 250-350 ppm. The results from the geochemical analysis of the gas sample indicated that methane is of a thermogenic origin. These results suggest that gas migration pathways develop near the Omagari anticline axis.

At the Omagari fault, methane anomalies distributed at intervals of about 20 to 50 m with smaller concentrations, 2 to 7 ppm, compared with the anticline area, over roughly 150 m sections on both sides of the fault. Methane increase was detected at some open fractures in the outcrop of the Wakkanai formation mudstone. These results suggested that the migration pathways are created within networks of fractures associated with the fault.

Methane anomalies were also found near the boundary of the Yuchi and Koetoi Formation, which is located approximately 500m west of the Omagari Fault. The maximum methane concentration was about

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40 ppm.

From the existing geological surveys, anticline structures were identified on the east side of the Omagari Fault and a branching fault was inferred on the west side of the Omagari fault.
By combining our methane measurement results and the existing knowledge of the geological structure, we depicted three possible gas migration pathways in the vicinity of the Omagari Fault, i.e., (1) fractures at the anticline axis, (2) fracture zone of the Omagari Fault, and (3) the frontal margin fault.

Although more data needs to be accumulated in the future, this measurement technique is expected to become one of the promising tools in characterizing migration pathways on a regional scale.

Keywords: methane, fault, cavity-ringdown spectroscopy, gas migration, exploration, concentration measuremet

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