Origin of deep methane from pull-apart basin on the Itoigawa-Shizuoka Tectonic Line: Impacts between deep carbon and surface ecosystem in Lake Suwa

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Lake Suwa, located at the intersection of the Itoigawa-Shizuoka Tectonic Line (ISTL) and the Median Tectonic Line (MTL), is the most active fault lake in Japan. Lake Suwa is shallow, with an average depth of 4.3 meters and a maximum depth of 6.3 meters. Since the lake has a large catchment area (512 m^2) and 31 inflowing rivers, it has a sedimentary layer more than 370 m thick with a high annual sedimentation rate (~1 cm/yr). The benthic sediments of Lake Suwa are rich in organic matter (TOC ~5.5 wt%) and contain methane-rich bubbles, which are produced by benthic microorganisms, including methanogenic archaea [1]. Furthermore, a natural gas field, which is dissolved in a deep aquifer, is formed in the deep sedimentary layer, and several active seep sites are observed in the lake [1, 2]. In addition, there are several hot spring wells (Kamisuwa and Shimosuwa hot springs) along with the active fault group on the northern shore of the lake. Helium isotope ratio analysis of gases associated with hot spring water indicated that the gas associated with the hot spring water around Lake Suwa included a contribution by gas originating from the mantle [3]. These hot spring wells are also scattered throughout Lake Suwa and are an influential factor in the physical heterogeneity in the formation of lake icing during the severe winter season [4].

In summary, there are three origins of methane emission in Lake Suwa: 1) from the surface hydrosphere, 2) from deep sedimentary layers, and 3) from the mantle. In this study, we are investigating the interaction of these methane sources on the hydrosphere ecosystem using radiocarbon measurement. Methane and carbon dioxide collected at seep sites, where gas inflow was regularly observed in Lake Suwa, were ^{14}C-depleted ($\Delta^{14}C_{CH4}$ = −989.8 ±0.3‰, $\Delta^{14}C_{CO2}$ = −951.2 ±1.0‰). The results clearly indicated that the origin of methane is different from that of methane released from the benthic sediments ($\Delta^{14}C_{CH4}$ = +21.7 ±3.8‰). The $\Delta^{14}C$ values of dissolved inorganic carbon (DIC) in surface lake water collected at seep sites ($\Delta^{14}C_{DIC}$ = −103.1 to −630.6‰) and near the lakeshore ($\Delta^{14}C_{DIC}$ = −100.9 ±3.5‰) suggested that the influence of deep carbon occurred not only around the seep sites but also at the lakeshore. Using the application of the new analytical method [5, 6], we confirmed that the signal of deep carbon is transmitted to algae and fish through DIC, and succeeded in quantitatively evaluating the picture of the utilization of deep-derived carbon including methane as a carbon source in the lake ecosystem.

This study was supported in part by the Japan Society for the Promotion of Science (JSPS) with the joint research between the JAMSTEC and Shinshu University.

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Keywords: Methane-specific stable carbon and radiocarbon profiles, Active seep gas, Dissolved inorganic carbon, Pull-apart basin

