Impact of carbon capture and storage on the methanogenic activity and pathway in a petroleum reservoir

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Deep subsurface petroleum reservoirs are candidate sites for carbon capture and storage (CCS). The feasibility of CCS has been mainly studied from a geological perspective. However, little is known about the effects of CO_2 storage on microbes inhabiting the reservoirs. To address this issue, we investigated the effects of the elevated CO_2 concentration on the methanogenic microbial community and function in a petroleum reservoir by high-pressure incubation experiments mimicking the *in situ* reservoir (55°C, 5 MPa) or CO_2 storage conditions. The microcosms were constructed using the production water and crude oil, pressurized with either N_2 or N_2+CO_2 (90:10) at 5 MPa and then incubated at 55°C. Methane production was observed with the decrease of acetate dissolved in the production water under both high and low CO_2 conditions. However, the stable isotope tracer experiments and molecular biological analyses for both microcosms consistently showed that the major methanogenic pathway under the *in situ* reservoir condition was acetate oxidation coupled with hydrogenotrophic methanogenesis, whereas acetoclastic methanogenesis occurred under the CO_2 storage condition. Based on thermodynamic calculations, acetoclastic methanogenesis is exergonic under the high CO_2 conditions, but acetate oxidation would be endergonic. These results clearly indicated that CO_2 storage into a high-temperature petroleum reservoir would cause a drastic change in the methanogenic pathways. Importantly, the elevated CO_2 concentration invokes the methanogenic pathway (acetoclastic methanogenesis) which is faster and more favorable for crude oil biodegradation. Our study presents a possibility of CCS for enhanced microbial production of natural gas in high-temperature petroleum reservoirs.