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Investigating In Situ Methanogenic Activity in Antrim Shale via Deuterium Injection

ELLIOTT BARNHART[1], HANNAH SCHWEITZER[2], MATTHEW VARONKA[1], ELIZABETH J TOMASZEWSKI[1], KILIAN ASHLEY[3], MICHAEL CARLEY[4], JAMES SCHRAMSKI[4], ANNA MARTINI[5], JENNIFER MCINTOSH[6], SARA L. CALDWELL ELDRIDGE[1], PAUL C. HACKLEY[1], MATTHEW FIELDS[7], ALFRED B CUNNINGHAM[7] AND SHUHEI ONO[8]

[1]U.S. Geological Survey
[2]NETL
[3]University of Southern California
[4]Riverside Energy
[5]Amherst College
[6]University of Arizona
[7]Montana State University
[8]Massachusetts Institute of Technology

Presenting Author: epbarnhart@usgs.gov

Microbial methane (CH_4) accumulations in terrestrial organic-rich subsurface reservoirs are prevalent worldwide, but the timing and ongoing nature of deep subsurface CH_4 generation remains uncertain. In this study, downhole sampling and an *in situ* injection of deuterated water (D_2O) were used to investigate the microbial communities and methanogenic activity in Antrim Shale within the Michigan Basin, USA. The Antrim Shale stands out for its secondary biogenic CH_4 production from depths of 150 to 600 meters. Three production wells were initially sampled across the northern portion of the Michigan Basin with diffusive microbial samplers to examine the microbial ecology and to inoculate laboratory microcosms. Methanogens were detected and CH_4 production was evident in microcosms from all three wells. Subsequently, one well underwent a 2384-liter injection of 0.084% D_2O to isotopically label newly generated CH_4 (i.e., CH_3D, CD_4 etc.). Gas samples were collected at 21, 50 and 71 days postinjection at the wellhead to monitor any changes in gas isotopes. At 85 days postinjection, 3179 liters of water was pumped to collect final gas and water samples. The results provided valuable insights into methanogenic microbial communities and their activity in subsurface environments, with broad implications for CH_4 resource assessments and environmental management. Understanding the spatiotemporal dynamics of CH_4 generation in the subsurface is crucial for informing resource exploitation strategies and implementing effective environmental conservation measures.